REFORM
OF
CHEMICAL AND PHYSICAL CALCULATIONS

C. J. T. HANSSEN C. E.

K962

Med
K962

22102071976

REFORM

OF

CHEMICAL AND PHYSICAL CALCULATIONS

REFORM

OF

CHEMICAL AND PHYSICAL CALCULATIONS

BY

C. J. T. HANSSEN C. E.

PRINTED UNDER THE PATRONAGE AND AT THE EXPENSE OF
THE »CARLSBERG FOUNDATION« IN COPENHAGEN
IN ENGLISH, DANISH AND GERMAN EDITION

PUBLISHED BY
E. & F. N. SPON, LIMITED. LONDON: 125, STRAND
NEW YORK: SPON & CHAMBERLAIN
1897

19132036

25064

WELLCOME INSTITUTE LIBRARY

Coll.	welMOmec
Call	
No.	QD

COPENHAGEN

PRINTED BY J. JØRGENSEN & CO. (M. A. HANNOVER)

Translation.

A reform in chemical and physical calculations

by **C. J. T. Hanssen.** C. E.

Introduction by Herr G. Karsten, Dr. phil., Professor of Physics at the University of Kiel, Geheime-Regierungsrath &c. &c.

Herr C. J. T. Hanssen has permitted me, to read the first 123 paragraphs of the manuscript of his book »Reform of chemical and physical calculations.

The exposure of the inaccuracy in determinations of fundamental values, in chemical and physical science, by neglect of a point, hitherto overlooked by scientific investigators, has in reading the volume, so forcibly convinced me of the correctness of Herr Hanssens deductions, and propositions, that I must wish, those may be noticed and taken into serious consideration by Chemists and Physiists.

Herr Hanssen introduces his book with the proposal, that Chemists and Physiists of all nations, should refer all observations and calculations on gravity to one common circle of latitude, in similar manner as Astronomers of all nations refer all determinations of time and longitude, to one meridian.

Herr H. compares the best determinations of the weight of 1 cbm. of oxygen, from which is found, that this increases from south to north; there must consequently be a latitude where one cub. metre of oxygen of 0^0 C and mean atmospheric density weighs *exactly* 10/7 kg. (near 41^0). This latitude the author proposes to adopt as *circle of international gravity.*

After determination of the velocity of falling bodies, the mean atmospheric pressure, and the boiling temperature of water at this latitude, does Herr H. calculate a very great number of chemical and physical values, and compares them with the best observations.

Herr H.'s explanation is so concise — he avoids discussion and lets chiefly the ciphers speak — that, to indicate the rich contents, it would almost be required to quote the entire volume. I limit my review, to pointing out the principal chapters, where Herr H. proves the influence of his fundamental determinations.

The first part contains calculations of absolute and relative weights, carried out in many examples; the second and more extensive part, contains calculations on heat.

From a collection of 30 determinations of the ratio between specific heat at constant volume and at constant pressure, which do not agree perfectly, does Herr H. deduct the ratio 17/12 = 1·4166 . . . . which is used in all further calculations; these comprise all values on heat, specific and latent heat, atomic heat, production of heat &c. As samples of the satisfactory results of Herr H.'s calculations and observations on heat produced by combustion, § 80 and Tab. XXIII may be mentioned.

I shall be pleased, if these lines can assist in recommending Herr Hanssens book to the attention of my scientific colleagues.

G. Karsten.

Kiel, 27. November 1893.

Preface.

When half a century ago, the author had the privilege to attend Professor Œrsted's physical lectures, the great philosopher introduced his subject, by saying: »*We study nature, to perceive and adore the sublime harmony, simplicity, and infinite*« »*wisdom in God's creation.*«

These words have ever since guided me, in my studies and in my engineering practice, and the old man now ventures, to publish some observations, methods, and calculations, illustrating the harmonious simplicity in nature, and serving to facilitate the study and practical application of physical and chemical science.

All the deductions contained in this volume, are based upon the natural laws of atomic combination, heating, expansion and compression of aeriform substances, discovered and proved by Berzelius, Boyle, Mariotte, Gay-Lussac, Joule, Dulong and others, upon a few of the best substantiated experiments, and upon the fact, discovered by the author, that, near the 41^0 of latitude, the specific gravity of oxygen gas of atmospheric density, at the temperature of freezing water, exactly is 1/700 of the gravity of distilled water, at its temperature of greatest density.

From this fact as a starting point, all *fundamental values* have been determined, and expressed with *absolute exactness* in units and vulgar fractions instead of approximately by rows of decimals, and the attentive reader and user of this volume will perceive, that my plain arithmetical method gives a clear insight into many facts and phenomena, absolute accuracy of results, and a facility of manipulation, not attainable by any other known method.

The results are illustrated by diagrams where required.

The author, for whom the writing of this book has been a work of love, has not spared study research and care, to make it clear, handy and correct, and he sincerely hopes that it may prove to be useful to many.

The book is being published under the Patronage and at the Expense of the **„CARLSBERG FOUNDATION“** of **Copenhagen,** simultaneously in an English, a Danish and a German Edition.

The Author,
C. J. T Hanssen. C. E.

Copenhagen. April 1897.

List of Contents.

	Paragraph.	Page.	Table.	Diagram.
Introduction	1	1		
Weight of Oxygen	2	2		
International Circle of Gravity	3	2		
Velocity of falling. Length of Second Pendulum	4	2		
International atmospheric Pressure	5	2		
Boiling Temperature of Water	5	2		
Normal Barometer	5	2		
» Thermometer	6	3		
Absolute Zero of Temperature	7	3		
Specific Gravity. Relative Weight	8	3		
Weight of Gases pr. 1 cbm.	9	3		
Volume of Gases pr. 1 kg.	9	3		
Relative Weight H = 1. (Tab. I pag. 10—11)	10	3		
Specific Weight, Water = 1. (Tab. II pag. 12—13)	10	3		
Water (aeriform) H_2O. Composition Weight & Volume	11	3		
» (liquid) » » »	12	4		
» (Steam) » » »	13	4		
Carbon monoxide » » »	14	4		
» dioxide » » »	15	4		
Methane » » »	16	5		
Acetylene » » »	17	5		
Ethylene » » »	18	5		
Dypropyl » » »	19	5		
Alcohol » » »	20	5		
Ether » » »	21	6		
Atmospheric Air (without CO_2) » » »	22	6		
» » (with CO_2) » » »	23	7		
Coal Gas » » »	24	7		
Dowson Gas » » »	25	7		
Generator Gas » » »	26	8		
Watergas » » »	27	8		
Note to Tab. I & II » » »	28	8		
Specific, absolute and relative Weight of solid, liquid and aeriform Substances	29	8—9	III	
Weight pr. cbm. and Volume pr. kg. of Gases		10—11	I	
Composition of Gases by Volume and by Weight		12—13	II	

	Paragraph.	Page.	Table.	Diagram.
Heat. General Remarks	30	14		
Unit of Heat. Calor	31	14		
Specific Heat	32	14		
Relative Heat	33	14		
Heat at constant Volume and const. Pressure	34	14		
» » » » » » »	35	15	IV	
Heating and Expansion of Gases	36	14		
» of 1 kg. Hydrogen	37	14		
» » 1 cbm. »	38	14		
» » Gas Compounds	39	15		
Relative Heat of Gases	40	16	V	A
Specific Heat of Gases (Tab. VI p. 18)	41—42	17		
Expansion of Gases by Heat	43	17		
Specific Heat of Gases	42	18	VI	
Expansion of Gases by Heat	44—45	19	VII	
» » » » »	44—45	20	VIII	
The dynamic Equivalent of Heat	46	20		
» » » » »	47—48	21	IX	
Heating of simple and compound Gases		22	X	
Production of Heat by Compression of Gases	49—51	22		
» » » »	52—53	23		
» » » Logarithmic Table		23	XI	
» » by Compression of Gases	54—55	24		
» » » »		25		B
» » » »		26		C
» » » »	55—58	27		
» » » »	58—60	28	XII	
» » » »	61—64	29	XIII	
» » » »	65—66	30		
Water, solid, liquid, Steam, H_2O Gas and H & O	67	30		
» melts and evaporates not below $219\,^3/_8{}^0$ N abs.	68	30		
Heat required to melt, and to evaporate 1 kg. of Ice	69—70	31		
Ice, specific Heat 0·4	71	32		
Water in perfect or partial Vacuum	72	32		
Liquid Water, specific Heat = 1·0	73	32		
Heat contained in 1 kg. Ice of $219\,^3/_8{}^0$ N abs. and				
» in 1 kg. Water of 273^0 N abs.	74	32		
» in 1 kg. Steam of 373^0 N abs.	75—76	32		
Heat required to evaporate 1 kg. Ice of 0^0 N abs.		33		D
» 1 kg. Ice of 0^0 N abs., and for Decomposition into H & O		34		E
Heat required for Decomposition into H_2O Gas	77	35		
» for 1 kg. Ice into H & O	78	35		
Temperature and Volume of the Gases produced by Decomposition of 1 kg. Ice	79	35		
Calculation of the Heat, produced by Combustion of 1 kg. H with O	80	35		
Pressure exerted by Water congealing into Ice	81	35		
Evaporation of Water	82	36—37		
Water evaporates in Vacuum at $219\,^3/_8{}^0$ N abs.	83	37		
Production of Steam by combining H & O	84	37		
Weight of the Gases forming Steam 1/1000 to 100 Atmosphäres & 273^0 N abs.	85	37	XIV	
Weight of 1 cbm. and Volume of 1 kg. Steam from 1/1000 to 100 Atm. & 273^0 N abs.	86	37		
Volume of 1 kg. and Weight of 1 cbm. Steam of 1 Atm. and 273^0 N abs.	87	38		
Temperature where 1 cbm. Steam of 1 Atm. = 1 kg.	88	38	XV	

	Paragraph.	Page	Table.	Diagram
Real Weight of 1 cbm. saturated Steam at the Temperature due to its Pressure	89	39		
Boiling Temperature of Water of 0 – 10000 Atm.	90	39	XVI	
» » » »	91	39		
» » » »	92	40	XVII	
» » » »	93	40		
Evaporation of 1 kg. Ice and Water		41		F
Boiling Temperature of Water	94—95	51	XVIII	
Temperature, Pressure, Volume, V × P and Heat contained in one kg. of saturated Steam		42—44	XIX a-b	
Pressure and Weight of saturated Steam		45		G
Temperature, Pressure, Weight and Heat in one cbm. of saturated Steam		46—48	XX a-b	
Heat in 1 cbm. Steam, 0 to 15 Atm.		50		H
Explanation of Diagrams F & G.		49—51		
Boiling Temperature of Water	94—95	51		
» » » (see Tab. XVII—XVIII, Diagr. F, G, H)	96	52		
Weight pr. cbm., Volume pr. kg. Steam, Temperature and P × V	97	52		
Heat in 1 kg. Steam	98—99	52—53		
Temperature and latent Heat pr. 1 kg. and 1 cbm. Steam of $219^3/_8$ to 480^0 N abs.	100	53		
Formula for Calculation of Temperature, Pressure, Volume & Weight of Steam	101	53		
Caloric Energi of Steam against amospheric Resistance	102	53		
The Product P × V for various Temperatures	103	54		
Determination of Weight and Volume of Steam by graphic Construction	104	54		
Relative Weight of Steam for any Pressure and Temperature	105	54		
Combustion. General Remarks	106—108	54—55		
» Results of Experiments	109	55	XXI	
» of Hydrogen (pr. 1 kg.) with Oxygen	110	55		
» » » (pr. 1 cbm.) » »	111	55		
» » Oxygen with other Substances	112	55		
» » aeriform Carbon to CO	113—114	55		
» » » » » CO_2	115	56		
» » Carbon monoxide » CO_2	116	56		
» » solid Carbon » CO_2	117	56		
» » » » » CO	118	56		
» » Hydrocarbons	119	56		
Decomposition of Hydrocarbons by the united Action of Heat and the Affinity of O	120	56		
Combustion of Methane	121	57		
» » Acetylene	122	57		
» » Ethylene	123	57		
» » Ethane	124	57		
» » Allylene	125	57		
» » Gases. Products of Combustion		58	XXII	
» » Propylene	126	59		
» » Propane	127	59		
» » Butylene	128	59		
» » Butane	129	59		
» » Pentane	130	60		
» » Benzene	131	60		
» » Dipropyl	132	60		
Production of Heat, calculated and Results of Experiment		61	XXIII	
Combustion of Coal Gas	133	62		
» » Dowson Gas	134	62		
Combustion of Generator Gas	135	62		

	Paragraph.	Page.	Table.	Diagram.
Production of Watergas (H + CO)	136	63		
» » » »	137	63		
Combustion » »	138	63		
» of liquid Hydrocarbons	139	64		
» » Dyallyl	140	64		
» » Hexane	141	64		
» » Styrol	142	64		
» » Petroleum	143	64		
» » liquid C. H. O. Compounds	144	64		
» » » Acetylenclicarbondioxide	145	65		
» » » Fumardioxide	146	65		
» » » Safrol	147	65		
» » » Hexahydromallitdioxide	148	65		
» » Gases and other Substances with atmospheric Air	149	65		
Laboratoriy and working Temperature	150	66		
The atmospheric Pressure modifyed by Gravity and geographic Latitude	151	66		
Explanation of Diagram I		66		
Diagram of atmospheric Pressure		67		I
Vapour of Water in the Atmosphere	152	67		
» » » » »		68	XXIV	
» » » » »		69		K
Homogeneous Columns of liquid and aeriform Substances equal to atmospheric Pressure	153	70		
Theoretic Velocity of Efflux into the Vacuum	154	70		
Velocity of Efflux of hot, cold, compressed or expanded Gases into a Vacuum	155—156	70		
Homogeneous Columns of Liquids and Gases = 1 Atm. Theoretic Velocity of Efflux		71	XXV	
Velocity of Efflux against external Pressure	157	71		
The relative Weight of saturated Steam of any Pressure and Temperature	158	71		
» » » » Gases of any Pressure and Temperature	159	72		

Errata.

Page	9	Tab. I	Col. 7		instead of	0·0892875,	read	0·0892857.
»	14	§ 33		bottom line	» »	at	»	or.
»	19	Tab. VII	» 4		» »	$372^{15}/_{17}$	»	$372^{15}/_{16}$.
»	35	§ 80		bottom line	» »	×	»	+
»	46	Tab. XX a	» 1 —	4th line from bottom	» »	1·01	»	0·01.
»	47	» »	» 4 —	16th » » top	» »	0·671378	»	0·641378.
»	52	§ 96			» »	XVII & XVIII	»	XIX & XX.
»	55	§ 111		3d » » top	» »	lb.	»	kg.
»	56	§ 116		3d » » »	» »	monoxide	»	dioxide.
»	63	§ 137		3d » » »	» »	C	»	O.
»	64	§ 143		3d » » »	» »	2/66	»	5/56.

Index.

Absolute Pressure of Steam 38 till 52.
» Temperature 2.
» Vacuum 31, 36, 66.
» Weight 2, 7, 12.
Acetylene 4, 8, 9, 10, 11, 13, 15, 16, 19, 20, 71. 72, 68.
Acetylenclicarbon dioxide 65.
Adiabatic Compression of Gases 21, 22, 24, 25, 27.
» Coling of Gases 27.
» Expansion of Gases 27.
Air (atm.) 5, 6, 8, 9, 10, 11, 13, 66, 67, 68, 69.
Argon 3, 5, 6, 8, 9.
Atmospheric Air. Composition 6, 7.
» » Weight 6, 7, 10, 11, 68 til 71.
» » saturated with aqueous vapour 68, 69.
» Pressure normal 2, 66 till 71.
» » modifyed by geographic Latitude 66, 67.
Alcohol 5, 9, 10, 11, 12, 13.
Aluminium 9.
Allylene 10, 11, 12, 13, 16, 18, 19, 20.
Ammonia 10, 11, 12, 13.

Barometer, international 2, 3.
» Height of Mercury normal 2, 3.
» » at various Latitudes 66, 67.
Benzene 10, 11, 12, 13.
Benzol 9.
Bismuth 9.
Boiling Temperature of Water 2.
Butane 10, 11, 12, 13, 16, 18, 19, 20, 71.
Butylene 10, 11, 12, 13, 16, 18, 19, 20, 71.

Calor 14.
Caloric Energy 14, 18, 19, 20, 21, 22.
Carbon 3 til 8, 10 till 13, 15, 16, 18, 19.
Carbon aeriform 3, 10, 11, 12, 3.
» dioxide 4, 7, 10, 11, 12, 13, 15, 16.
» liquid 64.
» monoxide 4, 10, 11, 12, 13, 15, 16.
» solid 56.
Chemical Affinity 12, 13, 15, 17, 18, 19, 21, 56.
» Contraction of Gases 4, 5, 6, 7, 8, 10, 11, 12, 13, 16, 18, 19, 21.
Combustion 54, 55.
» of aeriform Carbon 55, 56.
» » liquid » 64.
» » solid » 56.
» » aeriform Hydrocarbons 56 til 61.
» » liquid » 64.
» » Hydrogen 35, 55.
» » H. C. O. Compounds 64, 65.
» » Gases 55 til 63.
Compression of Gases 22 til 30.
» » » adiabatic 22, 23, 24, 25, 26, 27, 28, 29.
» » » isothermic 23, 25, 26, 29, 30.
Constant Pressure of Gases 14, 15, 16.
» Volume » » 14, 15, 16.
Cooling of Gases by adiabatic Expansion 28.

Decomposition of Ice and Water by Heat 35.
» » Hydrocarbons by Heat and chemical Affinity 56 til 62.
» » Steam by Heat 63.
Diagrams 16, 25, 26, 33, 36, 41, 45, 50, 67, 69 A. B. C. D. E. F. G. H. I. K.
Dowson Gas 7, 10, 11, 12, 13.
Dynamic Eqvivalent of Heat 20, 21.
Dypropyl 10, 11, 12, 13, 16.

Ethane 10, 11, 12, 13, 16, 18, 19. 20, 57, 58, 61.
Ether 6, 10, 11, 12, 13.

Ethylene 5, 10, 11, 12, 13, 16, 18, 19, 20, 57, 58, 61.
Evaporation of Ice 31, 32, 33, 34.
» » Water 30 till 54.
Explanation of Diagrams F & G 49.
» » » I 66.

Falling Bodies, Velocity 2.
Formulæ on Evaporation 30, 32, 35. 40, 49, 51, 54.
Fumardioxide 65.

Gases Compression, adiabatic 21, 22, 24, 25, 27.
» » isothermic 23, 25, 26, 29, 30.
» Columns homogeneous = 1 Atm. 70, 72.
» Efflux Velocity of 70, 72.
» Expansion adiabatic 28.
» » by heat 17, 19, 20.
Generator Gas 8.
Geographic Latitude and Gravity 2.
» » » Barometer 2, 66, 67.
» » » Thermometer 2.
Glycerine » » » 9.
Gold » » » 9.

Heat 14 till 30.
Heating of Gases 14 til 30.
Heat, Expansion of Gases by 17, 19, 20.
» Eqvivalent of 20, 21.
» Production by Combustion 31, 54 til 63.
» » » Compression of Gases 35.
» relative 14, 16.
» specific 14, 15, 17, 18.
» Unit (Calor) 14.
» Latent by Combustion of liquid Carbon 64.
» » » » » solid » 56.
» » » evaporating of Water 34, 35.
» » » melting af Ice 31.
» » » decomposing of Water 31.
Helium 3, 10, 11, 12. 13.
Hexane 64.
Hexahydromallit dioxide 65.
Homogeneous Columns of Gas and Liquids 70, 72.
Horsepower 21.
Hydrogen 3 till 16, 18, 20, 22, 23, 24, 29, 31.
Hydrocarbons. Composition & Weight 5, 6, 7, 10 till 13.
» Combustion 54 till 63.
Hyperbolic Logarithms 23.

Ice decomposed into H and O 34.
» Evaporation 30, 31, 32, 33, 34. 41, 42, 52.
» Melting 30, 31, 32, 33, 34, 41, 52.
» Pressure exerted in Congealing 35.
» specific Heat 32.

International atmospheric Pressure 2.
» Circle of Gravity 2.
» Observatory 2.
Introduction 1.
Iridium 9.
Iron 9.

Kilogramme 1.

Latent Heat of Combustion 56, 65.
» » » Evaporation 30, 34, 41, 52.
» » » Gasifying 56, 64.
» » » Liquefaction 30, 34, 41, 52.
Liquid C. H. O. Compounds. Combustion 64, 65.
» Hydrocarbons 64.
» Water 2, 3, 4, 30, 32.
Logarithmic Table 23.

Mercury 2, 9, 70, 71.
Metric Measure and Weight 1.
Meteorology 2, 66, 67, 68, 69.
Methane 5, 10, 13, 16, 18, 19, 20, 28, 56, 58, 61.

Normal atmospheric Pressure 2, 66, 70.
» Barometer 3.
» Latitude of Weight 2.
» Temperature 2.
» Thermometer 3.
» Weight of Gases.

Pentane 10, 13, 16, 18, 19, 20, 70, 71.
Petroleum 9, 64.
Physico-Chemical Observatory 2.
Platinum 9.
Pressure of the Atmosphere 2, 66 til 71.
» constant of Gases 14, 15.
» of congealing Water 36.
» » Steam 36 till 48.
Production of Heat by Compression of Gases 22 til 30.
» » » from H & O 37.
Propane 10, 13, 16, 18, 19, 20, 70, 71.
Propylene 10, 13, 16, 18, 19, 20, 70, 71.

Ratio between const. Pressure & const. Volumen of Gases 14, 20.
» of chemical Contraction 4. 13, 15, 16, 18, 19, 22.
» of Compression 22, 30.
Relative Heat 9, 14, 16.
» Volume of Gases 3, 10. 13, 70, 72.
» Weight » Gases 3, 13, 70, 72.
» » » Steam 70.

Specific Heat 15, 18.
» Weight 3.

Sulphur 9.
Sulphide of Hydrogen 10, 13.

Tables I II III IV V VI VII VIII
10, 11, 12, 13, 9, 15, 16, 18, 19, 20,
IX X XI XII XIII XIV XV XVI XVII
21, 22, 23, 28, 29, 37, 38, 39, 40,
XVIII XIX XX XXI XXII XXIII
41, 42—44, 46—48, 55, 58, 61,
XXIV XXV
68, 71.

Temperature absolute 2.
» of boiling Water atm. Pressure 2.
» » » in Vacuum 30, 31.
Temperature of frezing Water atm. Pressure 2.
» » Hydrogen burnt with Oxygen 35.
Thermometer, normal 3, 14.

Vacuum 31, 37, 70.
Volume of Gases constant 15, 20.
Volume of Gases relative 3, 10, 13, 70, 72.
» » Steam » 70.

Water chemical Composition 4, 10, 13, 30, 35.
» Column = 1 Atm. 70, 71.
» decomposed 35.
» Evaporation of 30 till 54.
» Gas (H. CO.) 8, 10 till 13, 61, 63, 71.

A REFORM

IN CHEMICAL AND PHYSICAL CALCULATIONS.

§ 1. The study of chemical and physical science, the understanding of the principles involved in chemical and physical phenomena and problems, and the rational application of the results of scientific investigation to practical purposes, would be made easy, if the observations related to these subjects, especially the weight of aëriform substances, were expressed and recorded in a more plain, uniform, and international manner than hitherto. In text-books and publications we find that hardly two authors agree in their statements of specific gravities and specific heats, especially of aëriform substances. Some authors reduce their weights to the 45^0 latitude and sea level, others to the latitude and elevation of London, Paris, Berlin &c. Some prefer the English standard weights and measures and the Fahrenheit thermometer, others the metric weights and measures and the Centigrade thermometer. In short, a great and serious confusion prevails in these matters, and last, but not least, differences occur between calculations and the results of experiments.

In the following pages the author will endeavour to show that the troubles mentioned can be got over in a very plain way, and to explain a method by which a great many difficult problems may be solved by simple arithmetical calculation, and with greater exactness than by any more elaborate method.

The proposed reform and method of calculation requires the use of a system of measure and weight which gives a simple relation between the unit of length (which determines volume), the unit of mass, and the unit of specific gravity. Such a relation is in theory found in the metric system of measure and weight*), and this

---

*) It is a well known fact, that the *metric standards* of measure and weight, which were constructed in the year 1799 and are deposited at the Bureau of weights and measures in Paris, are only *approximately* correct; but the purpose of this book requires *perfectly accurate* measure and weight, and adopting the Standard, or *Archiv Metre* as *unit of length* it is therefore in these pages assumed, that: 1 *cubic metre* contains *exactly* 1000 *litres* à 1000 ccm.
- 1 - - destilled water of 4^0 C weighs exactly 1000 kg.
- 1 litre » » » 1·000 kg. and
- 1 ccm. » » » 1·000 gram.

The existing errors in the *standards*, and in the Copies of them shonld be corrected as soon as possible.

system, therefore, may be used in the proposed method of calculation, and is used here, as no decimal system of measure and weight based on the Anglo-American units as yet is adopted and authorised.

The *unit of relative gravity* of aëriform substances should be *hydrogen*, because atmospheric air, now commonly adopted as unit, is not a simple substance, but a mixture of at least four different gases, whose proportions are subject to frequent changes, and therefore its gravity is not constant; moreover, its relations to other gaseous substances and to water con only be *approximately* expressed by a long row of decimals, which are tedious to manipulate.

The proper unit of gravity is *hydrogen*, but it is extremely difficult to find the weight of hydrogen accurately by experiment; it is therefore advisable to calculate it from the weight of oxygen and nitrogen, which .now have been determined with great accuracy. But even a suitable unit would be useless if its value were not adopted universally. Astronomers of all nations find it advisable and convenient, to adopt the meridian which passes through the observatory of Greenwich as the first, and to refer all observations of longitudes to that meridian. In a similar way, physicists and chemists of all nations must adopt a common *circle of latitude*, and all observations and calculations on gravity must be reduced to that latitude. An enormous saving of time and trouble would be the result of this simple measure.

§ 2. The *weight* of *oxygen* of 0° C and atmospheric density, as determined by Regnault, is per cubic metre—

At 45° latitude and sea-level = 1·42909 kg.
In Paris 48° 50′ 11·2″ and 60 m. above sea = 1·42913 -
In London 51° 30′ 49″ - 50 - » » = 1·42991 -
In Berlin 52° 30′ 16·7″ - 40 - » » = 1·43003 -
The weight of a cubic metre gas decreases from north to south, and at a certain latitude, between the 41 and 42°, and sea level, it will be = 1·4285714285 kg.

§ 3. This latitude the author takes the liberty to propose as the *Circle of international Gravity* because that figure of 10 decimals, the international weight of *one cubic metre of oxygen*, of atmospheric pressure and 0° C temperature, is *exactly* = 10/7 kilogramme.

At this latitude, say on the West Coast of Italy, an international physico-chemical Observatory and Laboratory should be established.

§ 4. At this latitude is the *Velocity of falling bodies* during the first second = 4·90115 m., the final velocity after 1 second falling = 9·80230 m., and the length of a pendulum making one oscillation pr. second = 0·993181 m.

§ 5. The mean *international atmospheric pressure* is
= 759·72353 mm. of mercury = } = { 10330·442 kg. per sq.m. =
= 10·330442 m. of water pressure } { 1·0330442 kg. pr. sq·cm. =
= 8113·5119982 kg. per circular m.
= 0·8113512 kg. per circular cm.

and the *boiling temperature of water* = 99·975° Celsius = 100° *normal Centigrade.*

If this atmospheric pressure is adopted as *international*, than it will be most convenient to denote all pressures, not by millimetres of mercury, but by *atmospheres* and *milli-atmospheres* (1·013 At., 8·250 At. &c.) and to divide the scales of Barometers, Manometers, Vacuummeters &c. in accordance therewith.

§ 6. The **Normal Thermometer,** adopted to boiling temperature of water at normal atmospheric pressure, is between freezing temperature and boiling temperature of water (0° Celsius and 99·975° Celsius), divided into 100° normal scale (100° N), One 0° N consequently boing 1/4000 less than one °C or 3999 °C = 4000° N.

§ 7. **Absolute Zero of Temperature,** is calculated to be = —272·85° C which is = — 272·92° N. The latter figure is nearer to the generally accepted —273° than the former and the temperature —273° N is therefore in this book adopted as *absolute Zero.* The freezing temperature of water consequently is 0° N = 273° N absolute.

§ 8. **Specific Gravity.** *Relative Weight.* Instead of expressing the weights of *Gases* and *Vapours* in relation to the weight of atmospheric air as *Unit*, *Hydrogen* of 0° N and normal atmospheric pressure is adopted as *unit*, but the determination of the exact weight of *Hydrogen* by experiment being very difficult, this weight is calculated by dividing the weight of *Oxygen* by 16, or the weight of *Nitrogen*, (which since the discovery of *Argon* is known correctly), by 14.

At the *Latitude of international Gravity*, the temperature of 0° N (273° N abs.) and normal atmospheric density we find thus:

§ 9. The **Weight** *of 1 cbm.*: *Relative weight*: *Volume of 1 kg.*

		kg.	kg.	kg.		cbm.	cbm.	cbm.
Hydrogen	H.	$\frac{10/7}{16}$	= 10/112 =	5/56	1	56/5	=	11·20
Oxygen	O.	10/7	=	80/56	16	7/10	=	0·7000
Carbon	C.	5/56 × 12	=	60/56	12	56/60	= 14/15 =	0·93333
Nitrogen	N.	5/56 × 14	=	70/56	14	56/70	= 4/5 =	0·8000
Argon	A.	5/56 × 20	=	100/56	20	56/100	= 14/25 =	0·5600
Helium	η.	5/56 × 4	=	20/56	4	56/20	= 14/5 =	2·8000
Sulphur	S.	5/56 × 32	=	160/56	32	56/160	= 7/20 =	0·3500

§ 10. The **weights** *stated in* **relation to Hydrogen** as **Units** are in this book named *Relative weights.* The expression *Specific Gravity* is only used, where the weight of a substance is stated in relation to the *weight* of *water* as *unit.*

For *compound gases and vapours*, the calculation of absolute weight, relative weight and atomic weight, is thus:

§ 11. **Water** *(aëriform)* H_2O of 273° N absolute (0° N) and atmospheric density,

2 cbm. hydrogen à 5/56 kg. = 10/56 kg. combine with
1 - oxygen = 80/56 — forming

2 cbm. aëriform water = 90/56 kg. consequently
1 - » » = 45/56 - consist of $1\frac{1}{2}$ cbm. of simple
gases, and 1 kg. of aëriform water contains 56/45 cbm., and consists of 1/9 kg. of

hydrogen and 8/9 kg. of oxygen, or of 56/5 × 1/9 kg. = 56/45 cbm. of hydrogen and 7/10 × 8/9 = 56/90 or 28/45 cbm. of oxygen, of 273° N absolute and normal atmospheric density.

The *relative weight* of aëriform water (hydrogen being = 1) is found by the proportion: 5/56 kg. (hydrogen) : 45/56 kg. (aëriform water) = 1 (hydrogen) : 9 (aëriform water).

Ratio of chemical contraction. In combining to form aëriform water, the 3 cbm. of simple gases have contracted into 2 cbm. consequently, the ratio of contraction is = 3 : 2.

§ 12. **Composition of liquid water.** By weight, as shown above, hydrogen is 1/9 and oxygen 8/9 of the weight of vapour, and consequently also of liquid water. 1 cbm. of liquid water of 4° N (277° N absolute), weighing 1000 kg., consequently consists of:

1000/9 kg. = $111^1/_9$ kg. = 111·111111 kg., or 11200/9 cbm. = $1244^4/_9$ cbm. H.
8000/9 - = $889^8/_9$ - = 888·888888 - » 5600/9 - = $622^2/_9$ - O.

1000 kg. of water = 1 cbm. consists of $1244^4/_9$ cbm. of hydrogen + $622^2/_9$ cbm. of oxygen = $1866^2/_3$ cbm. of simple gases, and the *relative weight* of liquid water, as compared to hydrogen is found by the proportion:

1000 kg. (water) : 5/56 kg. (hydrogen) = 56000/56 : 5/56 = 11200.

Chemical Contraction. As 3 cbm. of simple gases combine to form 2 cbm. of H_2O, the chemical contraction is = 3 : 2.

§ 13. The **volume of steam** of atmospheric density, and 0° N (273° N absolute) would, if steam of atmospheric density could exist as *steam* at that temperature, be found thus:

1 cbm. water consists of $1866^2/_3$ cbm. of simple gases, of atmospheric density and 0° N (273° absolute). In combining, these contract, at the ratio 3 : 2, and consequently form 2/3 × $1866^2/_3$ = $1244^4/_9$ cbm. of vapour, of the initial temperature and pressure of the component gases. (See article »Steam«, § 85).

§ 14. **Carbon monoxide.** CO.

1 cbm. aëriform carbon, weighing = 60/56 kg. combines with
1 - oxygen » = 80/56 - forming

2 cbm. carbon monoxide, weighing = 140/56 kg. consequently
1 - » » = 70/56 - and
1 kg. » » contains 56/70 = 4/5 cbm.

Relative weight: 5/56 kg. : 70/56 kg. = 1 : 14.

Chemical contraction does not take place in the formation of this gas.

§ 15. **Carbon dioxide.** CO_2.

1 cbm. aëriform carbon, weighing = 60/56 kg. combines with
2 - oxygen à 80/56 kg. = 160/56 - forming

2 cbm. carbon dioxide weighing = 220/56 kg. consequently
1 - » » weighs = 110/56 - and
1 kg. » » contains = 56/110 cbm. of 0° N (273° N absolute) and atmospheric density.

Relative weight: 5/56 kg. : 110/56 kg. = 1 : 22.
Chemical contraction: the gases in combining, contract in the ratio 3 : 2.

§ 16. **Methane.** CH_4.
1 cbm. carbon = 60/56 kg. combines with
4 - hydrogen à 5/56 kg. = 20/56 - forming
2 cbm. methane = 80/56 kg. consequently
1 - » = 40/56 - and 1 kg. = 56/40 cbm. = 7/5 cbm.
Relative weight: 5/56 kg. : 40/56 kg. = 1 : 8.
Chemical contraction: the gases in combining, contract in the ratio 5 : 2.

§ 17. **Acetylene.** C_2H_2.
2 cbm. carbon à 60/56 kg. = 120/56 kg. combine with
2 - hydrogen à 5/56 - = 10/56 - forming
2 cbm. acetylene = 130/56 kg. consequently
1 - » = 65/56 - and 1 kg. = 56/65 cbm.
Relative weight: 5/56 kg. : 65/56 = 1 : 13.
Chemical contraction: the gases in combining, contract in the ratio 4 : 2.

§ 18. **Ethylene.** C_2H_4.
2 cbm. carbon à 60/56 kg. = 120/56 kg. combine with
4 - hydrogen à 5/56 - = 20/56 - forming
2 cbm. ethylene = 140/56 kg. consequently
1 - » = 70/56 - and 1 kg. 56/70 cbm. = 4/5 kg.
Relative weight: 5/56 kg. : 70/56 kg. = 1 : 14.
Chemical contraction: the gases in combining, contract in the ratio 6 : 2

§ 19. **Dypropyl.** C_6H_{14}. The vapour, of atmospheric density and 0^0 N (273^0 N absolute), consists of:
6 cbm. carbon à 60/56 kg. = 360/56 kg. combine with
14 - hydrogen à 5/56 - = 70/56 - forming
2 cbm. dypropyl = 430/56 kg. consequently
1 - » = 215/56 - and 1 kg. = 56/215 cbm.
Relative weight: 5/56 kg. : 215/56 kg. = 1 : 43.
Chemical contraction: the gases combining, contract in the ratio 20 : 2 = 10 : 1.

§ 20. **Alcohol.** C_2H_6O. Vapour of atmospheric density and 0^0C (273^0 absol.) consists of:
1 cbm. ethylene (C_2H_4) = 70/56 kg. combining with
1 - vapour of water (H_2O) = 45/56 - forming
1 cbm. vapour of alcohol = 115/56 kg. and 1 kg. = 56/115 cbm.
Relative weight: 5/56 kg. : 115/56 kg. = 1 : 23.
Chemical contraction: 1 cbm. ethylene consists of 1 cbm. C + 2 cbm. H and
1 - vapour of water of 1 - H + $^1/_2$ - O consequently 1 cbm. vapour of alcohol consists of $4^1/_2$ cbm. of simple gases, and the ratio of contraction is $4^1/_2$: 1.

§ 21. **Ether.** $C_4 H_{10} O$. Vapour of atmospheric density and 0^0 N (273^0 N absol.) consists of:

2 cbm. ethylene (C_2H_4) à 70/56 kg. = 140/56 kg. combine with
1 - vapour of water (H_2O) = 45/56 - forming

1 cbm. vapour of ether = 185/56 kg. consequently
1 kg. vapour of ether = 56/185 cbm.

Relative weight: 5/56 kg. : 185/56 kg. = 1 : 37.

Chemical contraction: 1 cbm. vapour of ether consists of:

2 cbm. C + 5 cbm. H + $^1/_2$ cbm. O = $7^1/_2$ cbm. of simple gases consequently ratio of contraction $7^1/_2$: 1.

§ 22. **Atmospheric Air.** Lord *Rayleighs* discovery of *Argon* in *atmospheric nitrogen;* calls for a revision of the composition of atmospheric air. According to Rayleighs and other recent experiments, is the weight of 1 cbm. air (containing 0·0003 volume parts of CO_2) at 0^0 C and 760 mm. density = 1·29372 kg. This would at international latitude, normal atmospheric pressure at sea level and 0^0 N of temperature be = 1·29327 kg. × 0·999636 = 1·292799 kg. pr. cbm. and under similar circumstances weighs *1 cbm. air, without CO_2* = 1·2925977 kg.
1 cbm. *oxygen* of 0^0 N and normal atm. pressure = 10/7 kg. = 1·4285714 -

difference in weight = 0·1359737 kg.

The mixture of gases hitherto termed, *atmospheric nitrogen*, consists of 79 parts (volume) of nitrogen and 1 part af argon, and this mixture consequently, at 0^0 N (273^0N absol) and normal atmospheric density, contains in 1 cbm.:

987500 ccm. nitrogen à 1/800 gramme = $1234^3/_8$ grm. and
12500 - argon - 1/560 - = $22^{18}/_{56}$ -

1000000 ccm. = 1 cbm. N + A = $1256^{39}/_{56}$ gr. = 1·256696 kg.
1 - O = $^{10}/_7$ kg. = 1·428571 -

difference in weight = 0·171875 kg.

The proportion of O and (N + A) in 1 cbm. of air (without CO_2) consequently is:

0·171875 kg. : 0·1359737 kg. = 1000000 ccm. : 791120 ccm. N + A.
1 cbm. = 1000000 - air without CO_2

208880 ccm. O.

1 cbm. air (without CO_2) contains: oxygen 208880 ccm.
791120 ccm. × 79/80 volume parts = nitrogen 781231 -
791120 - × 1/80 » = *argon* 9889 -

1 cbm. air = 1000000 ccm.

Air (without CO_2) at normal atmospheric pressure and 0^0 N (273^0 N absolute), consequently weighs pr. *1 cbm.*:

208880 ccm. O à 1/700 grm. = 298·4000 grm.
781231 - N - 1/800 - = 976·5388 -
9889 - A - 1/560 - = 17·6589 -

1000000 ccm. air = $1292^{3347}/_{5600}$ grm. = 1292·5977 grm. = 1·2925977 kg.

Air (without CO_2) at norm. atm. pressure and 0^0 N contains pr. 1 kg.

161597·08768 ccm. O à 1/700 grm. = 230·85300 grm.
604388·42592 - N - 1/800 - = 755·48550 -
7650·48640 - A - 1/560 - = 13·66150 -
773636·00000 ccm. *air* (without CO_2) = 1000·00000 grm. = 1 kg.

Relative weight: 5/56 : 1·2925977 = 1 : 14·477094.

§ 23. Air with 3/10000 volume parts CO_2 contains in 1 cbm.

208817·3 ccm. O à 1/700 grm. = 298·3104 grm.
780996·7 - N - 1/800 - = 976·2459 -
9886·0 - A - 1/560 - = 17·6536 -
300·0 - CO_2 - 11/5600 - = 0·5893 -
1000000·0 ccm. = 1 cbm. air (with CO_2) = 1292·7992 grm. = 1·2927992 kg.

Air with 3/10000 volume parts CO_2 contains in 1 kg.

161523·8 ccm. O à 1/700 grm. = 230·7478 grm.
604114·5 - N - 1/800 - = 755·1414 -
7647·0 - A - 1/560 - = 13·6552 -
232·0 - CO_2 - 11/5600 - = 0·4556 -
773517·3 ccm. air (with CO_3) = 1000·0000 grm. = 1 kg.

Relative weight: 5/56 : 1·2927992 = 1 : 14·47935

Chemical contraction: The 300 ccm. CO_2 contained in cbm. air consist of 450 ccm. C and O, consequently contains 1 cbm. air 1·000150 ccm. simple gases; contraction 1000150 : 1000000.

§ 24. **Coal Gas.** (17 *candle*) 1 cbm. contains:

Litres.		*Kg. pr. Litre.*	*Kg. in 1 cbm. Gas.*	*Litres of simple Gases.*
370	CH_4	à 40/56000	1480 /5600	925 combustible
25	C_2H_4	- 70/ »	175 / »	75 »
12	C_3H_6	- 105/ »	126 / »	54 »
13	C_6H_6	- 195/ »	253·5/ »	78 »
490	H	- 5/ »	245 / »	490 »
52·5	CO	- 70/ »	367·5/ »	52·5 »
32·5	N	- 70/ »	227·5/ »	32·5 incombustible
4·0	CO_2	- 110/ »	44·0/ »	6·0 »
1·0	O	- 80/ »	8·0/ »	1·0 »
1000 Litres		= 1 cbm.	2926·5/5600 kg. =	1714·00 Litres.

1 kg. = 11200/5853 cbm.

Relative weight: 5/56 kg. : 29265/56000 kg. = 1 : 5·853.

Chemical contraction: 1·714 : 1.

§ 25. **Dowson Gas:** 1 cbm. contains:

Litres.		*Weight pr. Litre.*	*Kg. in 1 cbm. Gas.*	*Litre of simple Gases*
260	H	à 5/56000	130/5600	260 combustible
220	CO	- 70/ »	1540/ »	220 »
60	CO_2	- 110/ »	660/ »	90 incombustible
460	N	- 70/ »	3220/ »	460 »
1000 Litres		= 1 cbm.	5550/5600 kg. =	1030 Litres simple Gases.

1 cbm. = 111/112 kg. = 0·991 kg., und 1 kg. = 5600/5550 cbm. = 112/111 = 1·009 cbm.

Relative weight: 5/56 kg. : 555/560 kg. = 1 : 11·1.
Chemical contraction: 103 : 100.

§ 26. **Generator Gas:** 1 cbm. contains:

Litres.		*Kg. pr. Litre.*	*Kg. in 1 cbm. Gas.*	*Litres of simple Gases.*	
65	H à	5/56000	325/56000	65	combustible
19	CH_4 -	40/ »	760/ »	47·5	»
237	CO -	70/ »	16590/ »	237·0	»
53	CO_2 -	110/ »	5830/ »	79·5	incombustible
626	N -	70/ »	43820/ »	626	»
1000	Litres = 1 cbm. =		67325/56000 kg.	1055·0	Litre simple Gases.

1 cbm. = 2693/2240 kg. = 1·202 kg.
1 kg. = 2240/2693 cbm. = 0·832 cbm.

Relative weight: 5/56 : 2693/2240 kg. = 1 : 13·465,
Chemical contraction: 1055 : 1000 = 211 : 200.

§ 27. **Water Gas,** 1 cbm. contains:

Litres.		*Kg. pr. Litre.*	*Kg. in 1 cbm. Gas.*	*Litres of simple Gases.*	
486	H à	5/56000	243/5600	486	combustible
4	CH_4 -	40/ »	16/ »	10	»
440	CO -	70/ »	3080/ »	440	»
33	CO_2 -	110/ »	363/ »	49·5	incombustible
37	N -	70/ »	259/ »	37	»
1000	Litres = 1 cbm. =		3961/5600 kg. =	1022·5	Litre of simple Gases.
	1 kg. =		5600/3961 cbm.		

Relative weight: 5/56 kg. : 3961/5600 kg. = 1 : 7·922.
Chemical contraction: 10225 : 10000 = 409 : 400.

§ 28. Tables I & II page 10—11 og 12—13 are calculated in the manner shown in §§ 10—27. — The *chemical contraction* is required for calculating the *specific heat* and *relative heat* of gases.

§ 29. Although it is customary, to state the specific gravity of solid and of liquid substances, with the *gravity* of *water as unit*, it will be convenient, to know the *relative weight* of such substances, compared with the *weight* of *hydrogen as unit*, and accordingly, the specific gravity snd absolute weight of various substances, ascertained by standard authors, are reduced to relative weight and arranged in table III page 9.

Table III.

Absolute specific Gravity and relative Weight of solid and liquid Substances.

Substance	Symbol	Specific Weight = Weight of 1 cubic decimeter in Kg. Water = 1	Relative Weight Hydrogen = 1
Iridium	Ir.	22·3482	250300
Platinum (rolled)	Pl.	21·4285	240000
Gold	Au.	19·2500	215600
Mercury (soltd)	Hg.	14·4643	162000
» (liquid 0° N)	»	13·5956	152270
Lead	Pb.	11·4017	127700
Bismuth	Bi.	9·8000	109760
Copper	Cu.	8·8500	99120
Nickel	Ni.	8·6375	96740
Iron	Fe.	7·8446	87860
Tin	Sn.	7·2902	81650
Zinc	Zn.	7·2098	80750
Aluminium	Al.	2·565	28730
Water (distill. 4° N)	H_2O	1·000	11200
Alcohol (absol. 0° N)	C_4H_6O.	0·79196	8870
Benzol	C_6H_4.	0·9000	10800
Petroleum (refined)	C_7H_{16}.	0·8000	8960
Dypropyl	C_6H_{14}.	0·675	7560
Glycerine	$C_3H_8O_3$.	1·2598	14110
Hydrogen (1 Atm. 0° N)	H.	1/11200	1·00000.

» 1 cbm. of normal atmospheric density and 0° N = 5/56 kg. = 0·089285 kg.
» 1 cubic decimeter = 1 Litre 5/56 gram = 0·089285 gram.

Tab. I.

Weight and Volume of simple

Normal atmospheric pressure

Substance.	Symbol.	1 Cbm. weighs Kg.	1 Kg. contains Cbm.
1	2	3	4
Simple Gases.			
Hydrogen	H	5/56	56/5
Oxygen	O	80/56 = 10/7	56/80 = 7/10
Carbon	C	60/56 = 15/14	56/60 = 14/15
Nitrogen	N	70/56 = 5/4	56/70 = 4/5
Argon	A	100/56 = 25/14	56/100 = 14/25
Helium	η	20/56 = 5/14	56/20 = 14/5
Sulphur	S	160/56 = 20/7	56/160 = 7/20
Compounds			
Water (liquid)	H_2O	1000	1/1000
» (aëriform)	H_2O	45/56	56/45
Carbon monoxide	CO	70/56 = 5/4	56/70 = 4/5
Carbon dioxide	CO_2	110/56 = 55/28	56/110 = 28/55
Methane	CH_4	40/56 = 5/7	56/40 = 7/5
Acetylene	C_2H_2	65/56	56/65
Ethylene	C_2H_4	70/56 = 5/4	56/70 = 4/5
Ethane	C_2H_6	75/56	56/75
Allylene	C_3H_4	100/56 = 25/14	56/100 = 14/25
Propylene	C_3H_6	105/56 = 15/8	56/105 = 8/15
Propane	C_3H_8	110/56 = 55/28	56/110 = 28/55
Butylene	C_4H_8	140/56 = 5/2	56/140 = 2/5
Butane	C_4H_{10}	145/56	56/145
Pentane	C_5H_{12}	180/56 = 45/14	56/180 = 14/45
Benzene	C_6H_6	195/56	56/195
Dypropyl	C_6H_{14}	215/56	56/215
Sulphide of hydrogen	SH_2	85/56	56/85
Ammonia	NH_3	85/112	112/85
Alcohol	C_2H_6O	115/56	56/115
Ether (sulph)	$C_4H_{10}O$	185/56	56/185
Mixed gases.			
Atm. Air (pure)	O. N & O	16157/12500	12500/16157
Atm. Air (with CO_2)	O. N. A. CO_2	808/625	625/808
Coal Gas (17 candles)		5853/11200	11200/5853
Dowson Gas	H. C. O. N.	111/112	112/111
Generator Gas	H. C. O. N.	2693/2240	2240/2693
Water Gas	H. C. O. N.	3961/5600	5600/3961

Tab. I.

§ 10—28.

Gases, Gascompounds and Mixtures.

and 0° N = 273° N absolute.

Relative weight.	Relative volume.	1 Cbm. weight Kg.	1 Kg. contains Cbm.	Substance.
5	6	7	8	9
				Simple Gases.
1	11200	0·0892875	11 20000	Hydrogen
16	700	1·42857	0·70000	Oxygen
12	2800/3	1·07143	0·93333	Carbon
14	800	1·25000	0·80000	Nitrogen
20	560	1·78575	0·56000	Argon
4	2800	0·35715	2 80000	Helium
32	350	2·85714	0·35000	Sulphur
				Compounds.
11200	1	1000	0·00100	Water (liquid)
9	11200/9	0·80357	1·24444	» (aëriform)
14	800	1·25000	0·80000	Carbon monoxide
22	5600/11	1·96428	0·50909	Carbon dioxide
8	1400	0·71428	1·40000	Methane
13	11200/13	1·16071	0·86154	Acetylene
14	800	1·25000	0·80000	Ethylene
15	2240/3	1·33929	0·74666	Ethane
20	560	1·78571	0·56000	Allylene
21	1600/3	1·87500	0·53333	Propylene
22	5600/11	1·964285	0·50909	Propane
28	400	2·50000	0·40000	Butylene
29	11200/29	2·58928	0·31500	Butane
36	2800/9	3·21428	0·31111	Pentane
39	11200/39	3·48214	0·28718	Benzene
43	11200/43	3·83928	0·26046	Dypropyl
17	11200/17	1·51786	0 65882	Sulphide of hydrogen
17/2	22400/17	0·75893	1·31765	Ammonia
23	11200/23	2·05375	0·48695	Alcohol
37	11200/37	3·30357	0 30270	Ether (sulph)
				Mixtures.
14·47709	773·639	1·29256	0·77364	Atm. Air (pure)
14·47935	773·522	1·29280	0·77352	Atm. Air (with CO_2)
5·853	1913·5	0 52259	1·91355	Coal Gas (17 candles)
11·1	1009·0	0·99107	1·00901	Dowson Gas
12·763	831·8	1·20235	0·83179	Generator Gas
7·922	1413·8	0·70732	1·41605	Water Gas

Tab. II. Weights and Composition by Volume and by

Normal atmospheric pressure

Substance.	Symbol.	1 Cbm. of compound contains Kg. simple Gases.	1 Kg. of compound contains Cbm. simple Gases.
1	2	3	4
Gas Compounds.			
Water (liquid)	H_2O	1000/9 H + 8000/9 O	56/45 H + 28/45 O
» (aëriform)	H_2O	5/56 H + 40/56 O	56/45 H + 28/45 O
Carbon monoxide	CO	30/56 C + 40/56 O	2/5 C + 2/5 O
Carbon dioxide	CO_2	30/56 C + 80/56 O	14/55 C + 28/55 O
Methane	CH_4	30/56 C + 10/56 H	7/10 C + 28/10 H
Acetylene	C_2H_2	60/56 C + 5/56 H	56/65 C + 56/65 H
Ethylene	C_2H_4	60/56 C + 10/56 H	4/5 C + 8/5 H
Ethane	C_2H_6	60/56 C + 15/56 H	56/75 C + 168/75 H
Allylene	C_3H_4	90/56 C + 10/56 H	21/25 C + 28/25 H
Propylene	C_3H_6	90/56 C + 15/56 H	4/5 C + 8/5 H
Propane	C_3H_8	90/56 C + 20/56 H	42/155 C + 112/155 H
Butylene	C_4H_8	120/56 C + 20/56 H	4/5 C + 8/5 H
Butane	C_4H_{10}	120/56 C + 25/56 H	112/145 C + 280/145 H
Pentane	C_5H_{12}	150/56 C + 30/56 H	35/45 C + 84/45 H
Benzene	C_6H_6	180/56 C + 15/56 H	56/65 C + 56/65 H
Dypropyl	C_6H_{14}	180/56 C + 35/56 H	168/215 C + 392/215 H
Sulphide of hydrogen	SH_2	80/56 S + 5/56 H	28/85 S + 56/85 H
Ammonia	NH_3	70/112 N + 15/112 H	56/85 N + 168/85 H
Alcohol	C_2H_6O	60/56 C + 15/56 H + 40/56 O	56/115 C + 168/115 H + 28/115 O
Ether (sulph)	$C_4H_{10}O$	120/56 C + 25/56 H + 40/56 O	112/185 C + 280/185 H + 28/185 O
Gas Mixtures.			
Atm. Air (pure)		1·29256 simple Gases	0·773646
Atm. Air (with CO_2)		1·29280 » »	0·773633
Coal Gas (17 candles)			11200/5853
Dowson Gas			112/111
Generator Gas			87·7536
Water Gas			5600/3961

Tab. II.

§ 10—28.

Weight of Gas Compounds and Mixtures.

and 0^{0} N = 273^{0} N absolute.

Relative Volume Water = 1.	1 Cbm of Compound contains Cbm. simple Gases.	1 Kg. of Compound contains Kg. simple Gases.	1 Kg. of Compound contains Cbm. simple Gases.	Ratio of chemical Contraction.
5	6	7	8	9
1	11200/9 H + 5600/9 O	1/9 H + 8/9 O	28/15	5600/3 : 1
11200/9	1 H + $^{1}/_{2}$ O	1/9 H + 8/9 O	28/15	$1^{1}/_{2}$: 1
800	$^{1}/_{2}$ C + $^{1}/_{2}$ O	3/7 C + 4/7 O	4/5	1 : 1
5600/11	$^{1}/_{2}$ C + 1 O	3/11 C + 8/11 O	42/55	$1^{1}/_{2}$: 1
1400	$^{1}/_{2}$ C + 2 H	3/4 C + 1/4 H	7/2	$2^{1}/_{2}$: 1
11200/13	1 C + 1 H	12/13 C + 1/13 H	112/65	2 : 1
800	1 C + 2 H	6/7 C + 1/7 H	12/5	3 : 1
2240/3	1 C + 3 H	4/5 C + 1/5 H	224/75	4 : 1
560	$1^{1}/_{2}$ C + 2 H	9/10 C + 1/10 H	49/25	$3^{1}/_{2}$: 1
1600/3	$1^{1}/_{2}$ C + 3 H	6/7 C + 1/7 H	12/5	$4^{1}/_{2}$: 1
5600/11	$1^{1}/_{2}$ C + 4 H	9/11 C + 2/11 H	14/5	$5^{1}/_{2}$: 1
400	2 C + 4 H	6/7 C + 1/7 H	12/5	6 : 1
11200/29	2 C + 5 H	24/29 C + 5/29 H	392/145	7 : 1
2800/9	$2^{1}/_{2}$ C + 6 H	5/6 C + 1/6 H	119/45	$8^{1}/_{2}$: 1
11200/39	3 C + 3 H	12/13 C + 1/13 H	112/65	6 : 1
11200/43	3 C + 7 H	36/43 C + 7/43 H	112/43	10 : 1
11200/17	$^{1}/_{2}$ S + 1 H	16/17 S + 1/17 H	84/85	$1^{1}/_{2}$: 1
22400/17	$^{1}/_{2}$ N + $1^{1}/_{2}$ H	14/17 N + 3/17 H	224/85	2 : 1
11200/23	1 C + 3 H + $^{1}/_{2}$ O	12/23 C + 3/23 H + 8/23 O	252/185	$4^{1}/_{2}$: 1
11200/37	2 C + 5 H + $^{1}/_{2}$ O	24/35 C + 3/35 H + 8/35 O	520/185	$7^{1}/_{2}$: 1
(§ 22)	(§ 22)	(§ 22)	0·773636	1·000 : 1
(§ 23)	(§ 23)	(§ 23)	0·773633	1·00015 : 1
1913·5	1·7140	(§ 24)	1714/1000	1·714 : 1
1009·0	1·03	(§ 25)	103/100	1·03 : 1
831·8	1·0550	(§ 26)	211/200	1·055 : 1
1413·8	1·0225	(§ 27)	409/400	1·0225 : 1

Heat.

§ 30. **The Normal Thermometer,** proposed by the author (§ 6) is in this book exclusively used to denote or express temperature, and its indications are written: °, °N (normal) and °N absol (degres normal absolute.); 1° N = 3999/4000° C. and 1° C. = 4000/3999° N. — If for comparaison the Celsius or Fahrenheit thermometer is mentioned, the quotations are written °C. or °F.

§ 31. **The normal Calorie** (*Calor* N or *Cal.*) consequently denotes in this book the *quantity of heat* required, to heat 1 kilogramme (kg.) of water, of 0°N (273°N absol) 1° N. — This *Calor* is consequently = 3999/4000 of the metric calorie, and 1 *metric calorie* = 4000/3999 Calor N.

§ 32. **Specific heat** is according to general custom, expressed by the *specific heat* of *water as unit.*

§ 33. **Relative heat** means in this book the *ratio* of heat required to heat a certain weight or volume of any substance 1° N compared to the heat required to heat an equal weight at volume of *hydrogen* 1° N.

§ 34. **Specific heat.** The specific heat of gases at constant volume and at constant pressure and the ratio γ between both, is according to well known authorities stated in Table IV. page 15, § 35.

As the values in this table vary, even for the same substance, none of them seems to be absolutely correct. The author ventures, for γ to adopt the simple ratio of 12 : 17 = 1 : 1,4166666 which is a value very near the mean of the experiments, and this ratio has been used in calculating the table of specific heats, and in all other calculations in this volume.

§ 36. **Heating and expanding of gases.** If we adopt γ = 12 : 17 we find:
heating at *constant volume*, the internal work, to raise the temperature = 12 = 1·000000
and heating at *constant pressure*, the external work, expanding the molecules of the gas, and overcoming atmospheric pressure = 5 = 0·416666
total energy spent, heating at *constant pressure* = 17 = 1·416666

§ 37. *Specific heat of water being taken as unit*, and 1 kg. of water heated 1°.N = 1 Calor, adopted as the standard unit af heat, than according to the best authorities, heating 1 kg. of hydrogen 1° N requires 3·3996 to 3·4046 calors. The author has adopted the intermediate value of 3·4000 calors for heating 1 Kg. of hydrogen 1° N at *constant pressure*; and consequently are required:

3·4000 × 12/17 = 2·4000 calors for heating the same at *constant volume*

3·4000 × 5/17 = 3·4000 *for overcoming atmospheric resistance* (*external work*) in heating and expanding 1 kg. hydrogen 1° N at *constant pressure*.

§ 38. As 1 kg. of hydrogen of atmospheric density and 0° N (273°N absolute), 56/5 = 11·2 cbm. it follows, that heating 1 cbm. hydrogen of 0° C. and atmospheric density, 1° N

at *constant pressure*, requires 3·4/11·2 = 17/56 calor, and
at *constant volume* 2·4/11·2 = 12/56 calor, and for *external work*,
when heating at *constant pressure*, 1·0/11·1 = 5/56 calor.

From these data all others may be found, by the simple method, explained in the next paragraphs.

Table IV.

Specific Heat of Gases.

Water = 1.

§ 35.

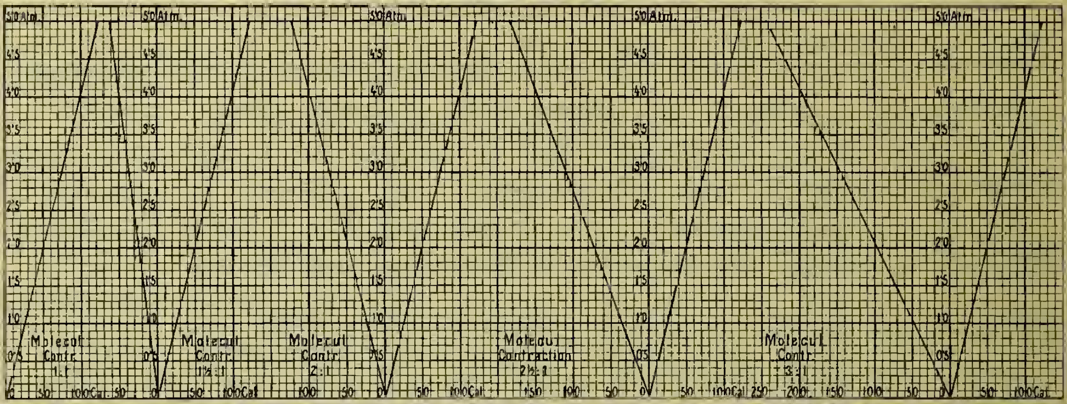
Substance.	Authority.	Constant Volume.	Constant Pressure.	Value of γ.
Hydrogen	Regnault	2·3910	3·4048	1 : 1·4239
»	Dulong			1 : 1·4210
»	Landolt & Börnstein			1 : 1·3852
Oxygen	Regnault	0·1547	0·2182	1 : 1·4105
»	Dulong			1 : 1·4210
»	Cazin			1 : 1·4100
Nitrogen	Regnault	0·1717	0·2440	1 : 1·4210
»	Dulong			1 : 1·4210
»	Cazin			1 : 1·4100
»	Kennedy			1 : 1·4030
Air (atmosph.)	Regnault	0·1668	0·2370	1 : 1·4208
» »	Dulong			1 : 1·4210
» »	Joule			1 : 1·4080
» »	Weisbach			1 : 1·4025
» »	Hirn			1 : 1·3885
» »	Masson			1 : 1·4149
» »	Cazin			1 : 1·4100
» »	Roentgen	(Mean of 70 Experiments)		1 : 1·4053
» »	Laplace			1 : 1·4210
» »	D. K. Clark	0·1688	0·2377	1 : 1·4076
» »	Kennedy			1 : 1·4080
» »	Moll & Beck			1 : 1·4085
» »	Szathamari	(Mean of 40 Experiments)		1 : 1·4027
Carbon monoxide	Regnault	0·1753	0·2479	1 : 1·4141
Carbon dioxide	Regnault	0·1702	0·2146	1 : 1·2608
»	Kennedy			1 : 1·2650
Water (aëriform)	Regnault	0·3621	0·4750	1 : 1·3170
»	Kennedy			1 : 1·2970
»	Landolt & Börnstein			1 : 1·2980
Acetylene	Regnault	0·3694	0·5204	1 : 1·4087
Argon				1 :
Helium				1 :

§ 39. From the law, that *equal volumes* of gases at *equal pressure* and *temperature*, contain *equal number* of *atoms* and that *equal number of atoms*, for raising their temperature 1° N require *equal quantity of heat*, it follows, that the simple gases, *hydrogen*, *oxygen*, *carbon*, *nitrogen*, and the compounds and mixtures, which have not been contracted by chemical affinity, such as *carbon monoxide*, *atmospheric air*, at 0° N (273° N absol) and normal atmospheric density, in 1 cbm. must contain *equal number of atoms*, and consequently pr. 1° N. increase of temperature, require equal quantity of heat, but that the compounds, which have been contracted by chemical affinity, such as *carbon dioxide*, H_2O, *methane*, *ethylene* &c in 1 cbm., *according to their ratio of contraction*, contain *more atoms than simple gases*, and therefore pr. 1° N rise of temperature, in equal proportion require more heat.

This is shown graphical in the subjoined Diagram.

Diagram A.

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.



H. O. C. CO_2 C_2H_2 CH_4 C_2H_4
N. A. η. H_2O
S. CO
Atm. Air

§ 40. **The Relative heat** of *simple gases* and *compounds* and the quaretity of heat (calories) required to heat 1 cbm. gas of 0^0 N (273^0 N abs) and atmospheric density, is, as shown in table V.

Table V.

	At constant Pressure pr. 1 cbm.	At constant Volume pr. 1 cbm.	Relative Heat H = 1.
Hydrogen Oxygen Carbon Nitrogen Argon Helium Carbon monoxide Atm. Air	34/112 Cal.	24/112 Cal.	1
Carbon dioxide Water (aëriform)	34/112 × 1½ = 51/112 Cal.	24/112 × 1½ = 36/112 Cal.	1½
Acetylene Ammonia	34/112 × 2 = 68/112 »	24/112 × 2 = 48/112 »	2
Methane	34/112 × 2½ = 85/112 »	24/112 × 2½ = 60/112 »	2½
Ethylene	34/112 × 3 = 102/112 »	24/112 × 3 = 72/112 »	3
Allylene	34/112 × 3½ = 119/112 »	24/112 × 3½ = 84/112 »	3½
Ethane	34/112 × 4 = 136/112 »	24/112 × 4 = 96/112 »	4
Propylene	34/112 × 4½ = 153/112 »	24/112 × 4½ = 108/112 »	4½
Propane	34/112 × 5½ = 187/112 »	24/112 × 5½ = 132/112 »	5½
Butylene Benzene	34/112 × 6 = 204/112 »	24/112 × 6 = 144/112 »	6
Butane	34/112 × 7 = 238/112 »	24/112 × 7 = 168/112 »	7
Pentane	34/112 × 8½ = 289/112 »	24/112 × 8½ = 204/112 »	8½
Dipropyl	34/112 × 10 = 340/112 »	24/112 × 10 = 240/112 »	10

§ 41. **The specific heat of Gases,** or the quantity of heat, required to raise the temperature of 1 kg. of any gas 1° N, is explained in §§ 36—40.

According to § 37 is required at *constant pressure* 3·400 cal. = 34/10 cal.
and at *constant volume* 2·400 » = 24/10 »
to heat 1 kg. hydrogen, 1° N.

For the simple, and not by chemical affinity contracted gases, do we find the specific heat, or the quantity of heat, required to heat 1 kg. of the gas, by *dividing the value found for H*, by the *relative weight* of the gas in question; and for *gases. contracted* by molecular affinity, do we find the specific heat, by *multiplying* the value for H by the *ratio of contraction*, and *dividing* by the *relative weight* of the gas in question.

§ 42. Table VI (page 18) shows these calculations, and the specific heat for various simple and compound gases.

§ 43. **The expansion of aëriform substances by heat.** As all gases and vapours *expand uniformly*, 1/273 = 0·003663 of their volume, by being heated 1° N, it follows, that 1 cbm. of any gas, heated at constant pressure from 0° N (273° N absol) to 273° N (546° N absol) or to 546° N (819° N absol) will expand to two, three, &c times its initial volume, but *the number of atoms in each cbm.* of the heated gas, will *decrease*, *as* the *absolute temperature* and *volume increase;* and at the same rate as the number of atoms pro cbm., decreases also the quantity of heat, required to raise the temperature of that cbm. of gas, or to expand its volume.

At all temperatures and pressures 1° N increase of temperature is required, to expand gas 1/273 th of its volume, but as stated, this 1° N of temperature absorbs more heat, if the gas is dense and cold, than if it is expanded and warm. In a *close vessel* (at constant volume) where the gas is unable to expand, *each* 1° N *increase* of temperature requires the same amount of heat pro cbm., but the quantity of heat required, is in *direct ratio* to the *initial density* of the gas inclosed and in *inverse ratio* to its *initial absolute temperature*. *One kg.* of gas, always contains its definite number of atoms, unaffected by temperature or pressure, and therefore the tabular number of calors will in all cases heat 1 kg. of gas 1° N or (at constant pressure) expand its volume 1/273 th, or (at constant volume) increase its pressure 1/273.

Example: 1 cbm. oxygen of 0° N (273° N absolute) and atmospheric density, if heated 91° N (to 364° N absol) at constant pressure, will form:
(1 cbm × 364°) : 273° = $1^1/_3$ cbm. of 1 atmosphere.

Heating 1 cbm. oxygen of 273° absol and atmospheric density 91° N, requires at constant pressure 91° × (tabular number) 17/56 calor = $27^5/_6$ calor, and heating 1 cbm. oxygen of 273° absol. and 2 atm. density, at constant pressure 91° N (to 364° absol.) will require 91° × 17/56 cal. × 2 atm. = $55^1/_4$ calors, and it will form $1^1/_5$ cbm. of 2 atmospheres density.

Heating 1 cbm. oxygen of 273° absol and 1 atm. density at constant volume 91° N to 364° N absol, will require 91° N × (tab. numb.) 12/56 cal. = $19^1/_2$ cal., its volume of course remains unaltered, but the pressure increases to $1^1/_3$ atmospheres.

Heating 1 cbm. oxygen of 2 atm. density and 273° absol to 91° N at constant volume, will require 91° N × 12/56 cal. × 2 atm. = 39 calors, and the ultimate pressure will be $2^2/_3$ atmospheres.

Specific Heat of Gases, or Calories, required to heat 1 kg. Gas 1° N.

	At constant Pressure. Calories.					γ 17 : 12 At constant Volume. Calories.					Relative. H = 1.	Difference between Const. Pressure & Const. Vol. External work pr. 1 Atm. pr. 1 kg. Gas.	
1	2		3	4	5	6		7	8	9	10	11	
Hydrogen	34/10	Cal.	Ratio of Contraction.	= 34/10	= 3·400	24/10	Cal.	Ratio of Contraction.	= 24/10	= 2·400	1	= 1·000	Cal.
Oxygen	$\frac{34/10}{16}$	»		= 34/160	= 0·2125	$\frac{24/10}{16}$	»		= 24/160	= 0·1500	1/16	= 0·0625	»
Carbon	$\frac{34/10}{12}$	»		= 34/120	= 0·2833	$\frac{24/10}{12}$	»		= 24/120	= 0·2000	1/12	= 0·0833	»
Nitrogen	$\frac{34/10}{14}$	»		= 34/140	= 0·2428	$\frac{24/10}{14}$	»		= 24/140	= 0·1714	1/14	= 0·0714	»
Argon	$\frac{34/10}{20}$	»		= 34/200	= 0·1700	$\frac{24/10}{20}$	»		= 24/200	= 0·1200	1/20	= 0·0500	»
Helium	$\frac{34/10}{4}$	»		= 34/40	= 0·8500	$\frac{24/10}{4}$	»		= 24/40	= 0·6000	1/4	= 0·2500	»
Carbon monoxide	$\frac{34/10}{14}$	»		= 34/140	= 0·2428	$\frac{24/10}{14}$	»		= 24/140	= 0·1714	1/14	= 0·0714	»
Atm. Air (with CO_2)	$\frac{34/10}{14·47935}$	»		= 34/144·7935	= 0·2348	$\frac{24/10}{14·47935}$	»		= 24/144·7935	= 0·1658	1/14·47935	= 0·0690	»
Carbon dioxide	$\frac{34/10}{22}$	»	× $1\frac{1}{2}$	= 51/220	= 0·2318	$\frac{24/10}{22}$	»	× $1\frac{1}{2}$	= 36/220	= 0·1636	3/44	= 0·0682	»
Water (aëriform)	$\frac{34/10}{9}$	»	× $1\frac{1}{2}$	= 51/90	= 0·5666	$\frac{24/10}{9}$	»	× $1\frac{1}{2}$	= 36/90	= 0·4000	1/6	= 0·1666	»
Acetylene	$\frac{34/10}{13}$	»	× 2	= 34/65	= 0·5231	$\frac{24/10}{13}$	»	× 2	= 24/65	= 0·3692	2/13	= 0·1611	»
Ammonia	$\frac{34/10}{17/2}$	»	× 2	= 4/5	= 0·8000	$\frac{24/10}{17/2}$	»	× 2	= 48/85	= 0·5641	4/17	= 0·2359	»
Methane	$\frac{34/10}{8}$	»	× $2\frac{1}{2}$	= 17/16	= 1·0625	$\frac{24/10}{8}$	»	× $2\frac{1}{2}$	= 3/4	= 0·7500	5/16	= 0·3125	»
Ethylene	$\frac{34/10}{14}$	»	× 3	= 51/70	= 0·7286	$\frac{24/10}{14}$	»	× 3	= 36/70	= 0·5143	3/14	= 0·2143	»
Allylene	$\frac{34/10}{20}$	»	× $3\frac{1}{2}$	= 119/200	= 0·5950	$\frac{24/10}{20}$	»	× $3\frac{1}{2}$	= 41/100	= 0·4200	7/40	= 0·1750	»
Ethane	$\frac{34/10}{15}$	»	× 4	= 68/75	= 0·9093	$\frac{24/10}{15}$	»	× 4	= 16/25	= 0·6400	4/15	= 0·2693	»
Propylene	$\frac{34/10}{21}$	»	× $4\frac{1}{2}$	= 51/70	= 0·7286	$\frac{24/10}{21}$	»	× $4\frac{1}{2}$	= 36/70	= 0·5143	3/14	= 0·2143	»
Propane	$\frac{34/10}{22}$	»	× $5\frac{1}{2}$	= 17/20	= 0·8500	$\frac{24/10}{22}$	»	× $5\frac{1}{2}$	= 3/5	= 0·6000	1/4	= 0·2500	»
Butylene	$\frac{34/10}{28}$	»	× 6	= 51/70	= 0·7286	$\frac{24/10}{28}$	»	× 6	= 36/70	= 0·5143	3/14	= 0·2143	»
Benzene	$\frac{34/10}{39}$	»	× 6	= 34/65	= 0·5231	$\frac{24/10}{39}$	»	× 6	= 24/65	= 0·3692	2/13	= 0·1539	»
Butane	$\frac{34/10}{29}$	»	× 7	= 119/145	= 0·8207	$\frac{24/10}{29}$	»	× 7	= 84/145	= 0·5793	7/29	= 0·2414	»
Pentane	$\frac{34/10}{36}$	»	× $8\frac{1}{2}$	= 289/360	= 0·8003	$\frac{24/10}{36}$	»	× $8\frac{1}{2}$	= 17/30	= 0·5666	17/72	= 0·2361	»
Dypropyl	$\frac{34/10}{43}$	»	× 10	= 34/43	= 0·7907	$\frac{24/10}{43}$	»	× 10	= 24/43	= 0·5581	10/43	= 0·2326	»

Tab. VII.

§ 44–45.

Expansion of aëriform Substances by Heat.

One cbm. Gas of normal atmospheric Density of 0^0 N (273^0 N abs.) heated to 273^0 N (546^0 N abs.)
Rise of Temperature 273^0 N. *Expansion at constant pressure* from 1 cbm. to 2 cbm.
Rise of pressure at *const. Volume* from 1 to 2 Atm.

	At const. Pressure.			At const. Volume.			External Work.		
1	2	3	4	5	6	7	8	9	10
Simple Gases and Gases not contracted by chemical affinity.	(See § 36 and 40.)								
	Calors.		Calors.	Calors.		Calors.	Calors.		Calors.
Hydrogen Oxygen Carbon Nitrogen Argon Helium Carbon monoxide Atm. Air	$34/12 \times 273^0$ =		$82\,^7/_8$.	$24/112 \times 273^0$		$58\,^1/_2$.	$10/112 \times 273^0$ =		$24\,^3/_8$.
Compounds.	Calors.	Ratio of Contraction.	Calors.	Calors.	Ratio of Contraction.	Calors.	Calors.	Ratio of Contraction.	Calors.
Carbon dioxide Water (aëriform)	$82\,^7/_8$ ×	$1\,^1/_2$	= $124\,^5/_{16}$	$58\,^1/_2$ ×	$1\,^1/_2$	= $87\,^3/_4$	$24\,^3/_8$ ×	$1\,^1/_2$	= $36\,^9/_{16}$
Acetylene Ammonia	$82\,^7/_8$ ×	2	= $165\,^3/_4$	$58\,^1/_2$ ×	2	= 117	$24\,^3/_8$ ×	2	= $48\,^3/_4$
Methane	$82\,^7/_8$ ×	$2\,^1/_2$	= $207\,^3/_{16}$	$58\,^1/_2$ ×	$2\,^1/_2$	= $146\,^1/_4$	$24\,^3/_8$ ×	$2\,^1/_2$	= $60\,^{15}/_{16}$
Ethylene	$82\,^7/_8$ ×	3	= $248\,^5/_8$	$58\,^1/_2$ ×	3	= $175\,^1/_2$	$24\,^3/_8$ ×	3	= $73\,^1/_8$
Allylene	$82\,^7/_8$ ×	$3\,^1/_2$	= $290\,^1/_{16}$	$58\,^1/_2$ ×	$3\,^1/_2$	= $204\,^3/_4$	$24\,^3/_8$ ×	$3\,^1/_2$	= $85\,^5/_{16}$
Ethane	$82\,^7/_8$ ×	4	= $331\,^1/_2$	$58\,^1/_2$ ×	4	= 234	$24\,^3/_8$ ×	4	= $97\,^1/_2$
Propylene	$82\,^7/_8$ ×	$4\,^1/_2$	= $372\,^{15}/_{15}$	$58\,^1/_2$ ×	$4\,^1/_2$	= $263\,^1/_4$	$24\,^3/_8$ ×	$4\,^1/_2$	= $109\,^{11}/_{16}$
Propane	$82\,^7/_8$ ×	$5\,^1/_2$	= $455\,^{13}/_{16}$	$58\,^1/_2$ ×	$5\,^1/_2$	= $321\,^3/_4$	$24\,^3/_8$ ×	$5\,^1/_2$	= $134\,^1/_{16}$
Butylene Benzene	$82\,^7/_8$ ×	6	= $497\,^1/_4$	$58\,^1/_2$ ×	6	= 351	$24\,^3/_8$ ×	6	= $146\,^1/_4$
Butane	$82\,^7/_8$ ×	7	= $580\,^1/_8$	$58\,^1/_2$ ×	7	= $409\,^1/_2$	$24\,^3/_8$ ×	7	= $170\,^5/_8$
Pentane	$82\,^7/_8$ ×	$8\,^1/_2$	= $704\,^7/_{16}$	$58\,^1/_2$ ×	$8\,^1/_2$	= $497\,^1/_4$	$24\,^3/_8$ ×	$8\,^1/_2$	= $207\,^3/_{16}$
Dipropyl	$82\,^7/_8$ ×	10	= $828\,^3/_4$	$58\,^1/_2$ ×	10	= 585	$24\,^3/_8$ ×	10	= $243\,^3/_4$

Tab. VIII.

§ 44—45.

Expansion of aëriform Substances by Heat.

One Kilogram Gas, expanded at constant Pressure, to double the volume or at constant Volume, to double the Pressure, by 273° N rise of Temperature, requires:

	At const. Pressure. 17.			At const. Volume. 12.			External Work. 5.		
1	2	3	4	5	6	7	8	9	10
	Calors.		Calors.	Calors.		Calors.	Calors.		Calors.
Hydrogen	34/10	× 273°	= 928·200	24/10	× 273°	= 655·200	10/10	× 273°	= 273.000
Oxygen	34/160	× »	= 58·0125	24/160	× »	= 40·950	10/160	× »	= 17·0625
Carbon	34/120	× »	= 77·350	24/120	× »	= 54·600	10/120	× »	= 22·750
Nitrogen	34/140	× »	= 66·300	24/140	× »	= 46·800	10/140	× »	= 19·500
Carbon monoxide									
Argon	34/200	× »	= 46·410	24/200	× »	= 32·760	10/200	× »	= 13·650
Helium	34/40	× »	= 232·050	24/40	× »	= 163·800	10/40	× »	= 68·250
Propane									
Carbon dioxide	51/220	× »	= 63·286	36/220	× »	= 44·673	15/220	× »	= 18·614
Acetylene	34/65	× »	= 142·800	24/65	× »	= 100.800	10/65	× »	= 42·000
Benzene									
Ammonia	68/85	× »	= 218·400	48/85	× »	= 154·164	20/85	× »	= 64 235
Methane	17/16	× »	= 290·0625	12/16	× »	= 204·750	5/16	× »	= 85·3125
Ethylene	51/70	× »	= 198·900	36/70	× »	= 140·286	15/70	× »	= 58·5000
Propylene									
Butylene									
Allylene	119/200	× »	= 162·435	84/200	× »	= 114·660	35/200	× »	= 47·775
Ethane	68/75	× »	= 247·520	48/75	× »	= 174·720	20/75	× »	= 72·800
Butane	119/145	× »	= 224·048	84/145	× »	= 158·151	35/145	× »	= 65·827
Pentane	289/360	× »	= 219·158	204/360	× »	= 154·700	85/360	× »	= 64·444
Dipropyl	34/43	× »	= 215·860	24/43	× »	= 152·372	10/43	× »	= 63·488
Water (aëriform.)	51/90	× »	= 154·666	36/90	× »	= 109·200	15/90	× »	= 45·500
Air (with CO_2)	34/144·7935	× 273°	= 64·105	24/144·7935	× 273°	= 45·251	10/144·7935	× 273°	= 18·855
See Tab. VI. Col.	4.			8.			10.		

§ 46. **The dynamic equivalent of heat,** or *the amount of dynamic energy due to one calor* of heat, will be found, by calculating the heating and expansion of gases at constant volume and at constant pressure (Tab. VII).

Atmospheric pressure is, according to § 5 = 10330·442 kg. pr. sqm. If a cylinder of 1 sqm sectional aerea fitted with a moveable piston (absolutely tight, and moving without friction) and containing 1 cbm. gas of 0° N (273° N absol.) and atmospheric density, then the gas being heated 273° N from 273° N absol. to 546° N absolute, its volume would be doubled, and the piston moving 1 m. against the pressure of the atmosphere, would perform work equal to 10330·442 kg. lifted 1 metre high = 10330·442 mkg. If the cylinder contains 1 cbm. hydrogen of 0° N (273° N absol.) and atmospheric density, it requires raising its temperature 273° N in order to double the volume of the gas:

at constant pressure 34/112 calor × 273° N
» » volume 24/112 » × 273°
difference 10/112 calor × 273° N = 2730/112 cal. = $24^{3}/_{8}$ = 24·375 cal.

These 24·375 calors perform the 10330·442 mkg. of external work, against the pressure of the atmosphere, consequently

24·375 cal. : 1 cal. = 10330·442 mkg. : 423·813 mkg.

§ 47. If this calculation is made for the other simple gases, oxygen, carbon, nitrogen &c, and the compounds, carbon monoxide and air, which in mixing have retained the initial volume of their components, exactly the same result is abtained; but compound gases, which in combining have contracted into less volume, give appearently different results, because, in order to expand them, caloric energy is absorbed, not only to overcome the resistance of the atmosphere, but also, to overcome the chemical affinity of the atoms, which, when the compound was formed, was active, decreasing its volume; if this is deducted, the result is exactly as with the simple gases.

§ 48. 1 cbm. carbon dioxide of 0^0 N (273^0 N absol.) and atmospheric density requires for heating it 273^0 N and doubling its volume:

at constant pressure 51/112 cal. × 273^0 N
» » Volume 36/112 » × 273^0 »

difference 15/112 cal. × 273^0N = 4095/112 cal. = $36^9/_{16}$ = 36·5625 cal.

but in combining, 3 volumes of simple gases contracted into 2 volumes of compound; in order to expand the gas, therefore 1/3 of the $36^9/_{16}$ calors = $12^3/_{16}$ calors is required to overcome the affinity of the atoms, and the remaining 2/3 of $36^9/_{16}$ = $24^3/_8$ cal. perform the external work against the resistance of the atmosphere, just as is the case with the simple gases. In Tab X are shown the results of similar calculation for a number of compound gases; they all agree perfectly, and confirm the doctrin, that 1 calor under all circumstances performs equal amount of work. The results of these calculations, 423·813 mkg. = 1 calor, also agree very closely with the result of Joules experiments 772 footpounds = 1 B. T. U. = 423·56 mkg. = 1 calor. (Tab. IX & X.)

One horsepower (metric) = 4500 mkg. pr. minute consequently is

$$= \frac{4500}{423·813} = 10·0618 \text{ calor (very nearly } 10^1/_{16} \text{ calor) and}$$

1 calor pr. minute = 16/161 metric horsepower

Tab. IX.

The dynamic Equivalent of Heat.

By Experiment determined by:

Regnault	1 Calor	= 437	meterkilogram.	
H. F. Weber		= 428·15	» »	
Rowland		= 426·83	» »	(= 778 footpounds pr. 1 B. T. U.)
Hirm		= 425·2	» »	
Perot		= 424·63	» »	
Dieterici		= 424·36	» »	
Joule		= 423·56	» »	(= 772 footpounds pr. 1 B. T. U.)

By Calculation determined by:

C. J. T. Hanssen	= 423·813	» »	(§ 46).

Tab. X.

Heating of simple and Compound Gases

af 273^0 N abs., and atmospheric density to 546^0 N abs. (273^0 N rise of temperature) requires pr. cbm. of gas according to § 44—45 & Tab., Col. 10:

	Total Calories.	Resistance of Atmosphere. Calories.	Chemical Affinity. Calories.
Simple Gases, and Compounds not contracted by chemical affinity.	$24^{3}/_{8}$	$24^{3}/_{8} = 1$	0
Gases contracted by chemical affinity $1^{1}/_{2}$ times.	$36^{9}/_{16}$	$24^{3}/_{8} = 1$	$12^{3}/_{16} = {}^{1}/_{2}$
» » 2 »	$48^{3}/_{4}$	$24^{3}/_{8} = 1$	$24^{3}/_{8} = 1$
» » $2^{1}/_{2}$ »	$60^{15}/_{16}$	$24^{3}/_{8} = 1$	$36^{9}/_{16} = 1^{1}/_{2}$
» » 3 »	$73^{1}/_{8}$	$24^{3}/_{8} = 1$	$48^{3}/_{4} = 2$
» » $3^{1}/_{2}$ »	$85^{5}/_{16}$	$24^{3}/_{8} = 1$	$60^{15}/_{16} = 2^{1}/_{2}$
» » 4 »	$97^{1}/_{2}$	$24^{3}/_{8} = 1$	$73^{1}/_{8} = 3$
» » $4^{1}/_{2}$ »	$109^{11}/_{16}$	$24^{3}/_{8} = 1$	$85^{5}/_{16} = 3^{1}/_{2}$
» » $5^{1}/_{2}$ »	$134^{1}/_{16}$	$24^{3}/_{8} = 1$	$109^{11}/_{16} = 4^{1}/_{2}$
» » 6 »	$146^{1}/_{4}$	$24^{3}/_{8} = 1$	$121^{7}/_{8} = 5$
» » 7 »	$170^{5}/_{8}$	$24^{3}/_{8} = 1$	$146^{1}/_{4} = 6$
» » $8^{1}/_{2}$ »	$207^{3}/_{16}$	$24^{3}/_{8} = 1$	$182^{13}/_{16} = 7^{1}/_{2}$

§ 49. **The Production of Heat by Compression of Gas.** In order to solve, by very simple calculation, a variety of problems, connected with the compression of gases &c., we only need to investigate the behaviour of hydrogen, and we shall have the key to the solution of similar problems, with all other gases.

It has been shown (in § 37 & 38) that to heat hydrogen of atmospheric density and 273^0 N absolute temperature, 1^0 N, is required:

	At const. Pressure.	*At const. Volume.*	*For external Work.*
pr. 1 kg.	3·4 calors	2·4 calors	1·0 calor
» 1 cbm 1 Atm. & 273^0 N abs.	34/112 cal.	24/112 cal.	10/112 cal.

§ 50. If a gas is compressed by dynamic or chemical force, than the power spent in this operation, is converted into caloric energy (heat), and if gas is expanded by heating or contracted by cooling, than caloric energy is converted into dynamic energy. — As a calor is a constant and definite quantity of energy, it is evident, that the *effect* of a calor in all cases must be a constant and definite value.

§ 51. If 1 cbm. of hydrogen of 1 atmospheres density, is compressed to 2 atmospheres, then the dynamic force spent in the operation is converted into heat, which, if not instantly absorbed (by cold water or by other suitable means) will increase the temperature of the compressed gas, and expand its volume above the measure prescribed by the law of Mariotte.

This, *adiatic compression*, therefore requires more power than should be necessary according to that law.

§ 52. If 1 cbm. hydrogen of 273° N absol. and atmospheric density is compressed to 2 atm., and the heat generated during compression, is absorbed by cold water (isothermic compression), then we get, in accordance with Mariottes law, $^1/_2$ cbm. hydrogen of 273° N abs. and 2 atm. pressure, and the water has absorbed the heat, which in the former case heated and expanded the gas.

§ 53. **Adiabatic compression of hydrogen.** The *ultimate volume* produced by adiabatic compression of 1 hydrogen is found, by *dividing* the *initial volume* of the gas, by the 12/17 power of the ratio of compression. To find the 12/17 power of the ratio of compression, we must use logarithms, and those required for this purpose, and the hyperbolic logarithms, for calculating isothermic compression, are arranged in tab. XI.

Tab XI.
§ 53.

Compression of Gases.

	Logarithm for adiabatic Compression.					*Logarithm for isothermic Compression.*
Ratio of Compression.	Log. of Ratio. of Compression.		Power.		Log. of 12/17 Power of Ratio of Compression.	Hyperbolic Logarithms of Ratio of Compression.
1	0·00000	×	12/17	=	0·00000	0·00000
1·5	0·1760913	×	»	=	0·12430	0·40546
2	0·3010300	×	»	=	0·21249	0·69315
2·5	0·3979400	×	»	=	0·28090	0·91629
3	0·4771213	×	»	=	0·33679	1·09861
3·5	0·5440680	×	»	=	0·38405	1·25276
4	0·6020600	×	»	=	0·42498	1·38629
4·5	0‘6532125	×	»	=	0·46109	1·50408
5	0·6989700	×	»	=	0·49339	1·60944
5·5	0.7403627	×	»	=	0·52257	1·70475
6	0·7781513	×	»	=	0·54928	1·79176
6·5	0·8129134	×	»	=	0·57382	1·87180
7	0·8450980	×	»	=	0·59654	1·94591
7·5	0·8750613	×	»	=	0·61769	2·01490
8	0·9030900	×	»	=	0·63748	2·07944
8·5	0·9294189	×	»	=	0·65660	2·14007
9	0·9542425	×	»	=	0·67358	2·19722
9·5	0·9777236	×	»	=	0·69016	2·25129
10	1·0000000	×	»	=	0·70588	2·30258
11	1·0413927	×	»	=	0·73510	2·39789
12	1·0791812	×	»	=	0·76177	2·48490
13	1·1139434	×	»	=	0·78631	2·56495
14	1·1461280	×	»	=	0·80903	2·63905
15	1·1760913	×	»	=	0·83018	2·70805
16	1·2041200	×	»	=	0·84997	2·77258
17	1·2304489	×	»	=	0·86855	2·83321
18	1.2552725	×	»	=	0·88607	2·89037
19	1·2787536	×	»	=	0·90265	2·94444
20	1·3010300	×	»	=	0·91837	3·01707
30	1·4771213	×	»	=	1·04267	3·40120
40	1·6020600	×	»	=	1·13087	3·68888
50	1·6989700	×	»	=	1·19927	3·91202
100	2·0000000	×	»	=	1·41176	4·60517

§ 54. *The rise of temperature*, and the ultimate absolute temperature, *produced* by *adiabatic compression* of gases, is found by *multiplying* the initial absolute temperature of the gas before compression, by the 5/17th power of the ratio of compression; but quite as easy, the temperature may be ascertained from the ultimate volume of the compressed gas, as shown in § 55.

If V denotes the initial volume (cbm.) of the uncompressed gas
P its initial pressure in atmospheres (absolute)
T its absolute temperature
P_1 its ultimate pressure atmospheres (absolute)
V_1 the ultimate volume of the compressed gas (cbm.)
T_1 » absolute temperature of the compressed gas.

$R = \frac{P_1}{P}$ = ratio of compressione; then we get:

$$V_1 = \frac{V}{R^{12/17}} = \log. V - \log. R^{12/17} = x \text{ cbm and}$$

$$T_1 = T \times R^{5/17} = \log. T + \log. R^{5/17} = y^0 \text{ N absolute.}$$

For 1 cbm. *hydrogen*, of 1 atm. abs. pressure and 273⁰ N abs. temperature, compressed to 2 atm. abs. we get volume:

$R = 2/1 = 2. \quad R^{12/17} = 2^{12/17} = \log. 0{\cdot}21249$
$V = 1$ cbm. $= \log. 0{\cdot}00000$
$V_1 = \log. 0{\cdot}00000 - \log. 0{\cdot}21249 = \log. \bar{1}{\cdot}78751 = 0{\cdot}61307$ cbm.;

and the temperature:

$R^{5/17} = 2^{5/17} = \log. 0{\cdot}08854$
$T = 273^0 \text{ N} = \log. 2{\cdot}43616$

$T_1 = \log. 2{\cdot}52470 = 334{\cdot}736^0$ N absolute, consequently
rise of temperature $334{\cdot}736^0$ N abs. — 273^0 N abs $= 61{\cdot}736^0$ N.

As 1 cbm. *hydrogen* of 1 atm. and 273⁰ N abs., at const. volume requires, 12/56 cal. = 3/14 cal. for 1⁰ N rise of temperature, it follows, that for 61·736⁰ N rise of temperature,

$61{\cdot}736^0 \text{ N} \times 3/14$ cal. $= 13{\cdot}229$ calories are converted into dynamic force.

§ 55. As 1 cbm. *hydrogen* of 1 atm. and 273⁰ N abs., compressed to 2 atm. form 0·61307 cbm. of 2 atm. and 334·736⁰ N abs. it follows, that 1 cbm., of compressed hydrogen $= \frac{1 \text{ cbm.}}{0{\cdot}61307} = 1{\cdot}63113$ cbm. of 1 atm. and 273⁰ N abs,; and as 1 cbm. of this temperature and pressure weighs 5/56 kg., so weighs 1 cbm. of the compressed gas $= 1{\cdot}63113$ cbm. $\times$ 5/56 kg. $= 0{\cdot}14563$ kg.

To compress 1 cbm. *hydrogen* of 1 atm. and 273⁰ N to 10 atm. do we find

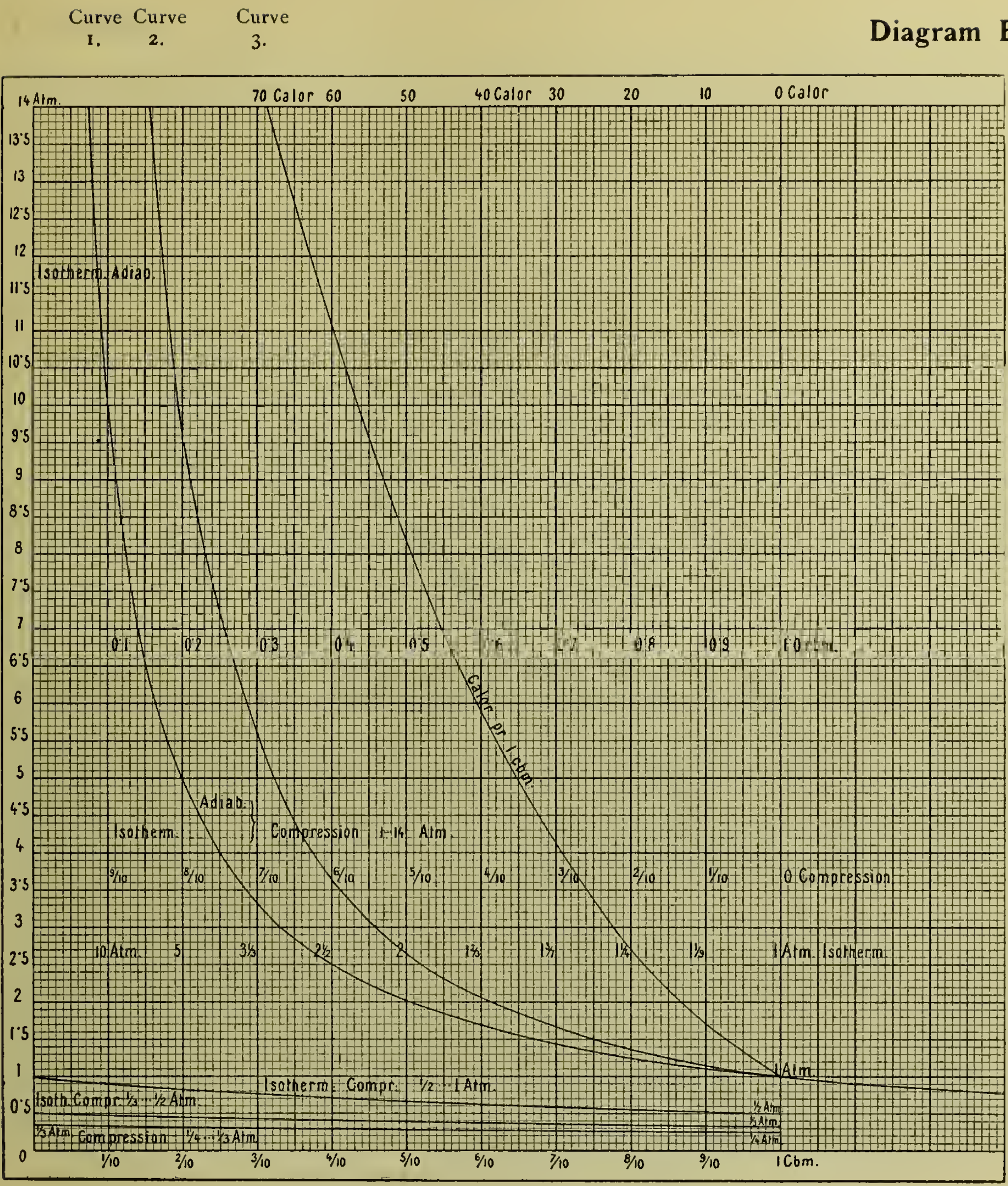
$$R = \frac{10 \text{ atm.}}{1 \text{ atm.}} = 10.$$

$R^{12/17} = 10^{12/17} = \log. 0{\cdot}70588$
$V = 1$ cbm. $= \log. 0{\cdot}00000$

$V_1 = \log. \bar{1}{\cdot}29412 = 0{\cdot}19684$ cbm.

(Continued pag. 27.)

Diagram B.



Compression of simple Gases, and of Gases which have not been contracted by chemical Affinity.

Curve 1 shows the ultimate volume of 1 cbm. gas, *isothermic* compressed from 1 atm. to 14 atmospheres.

Curve 2 shows ultimate volume of 1 cbm. gas *adiabatic* compressed from 1 atm. to 14 atmospheres.

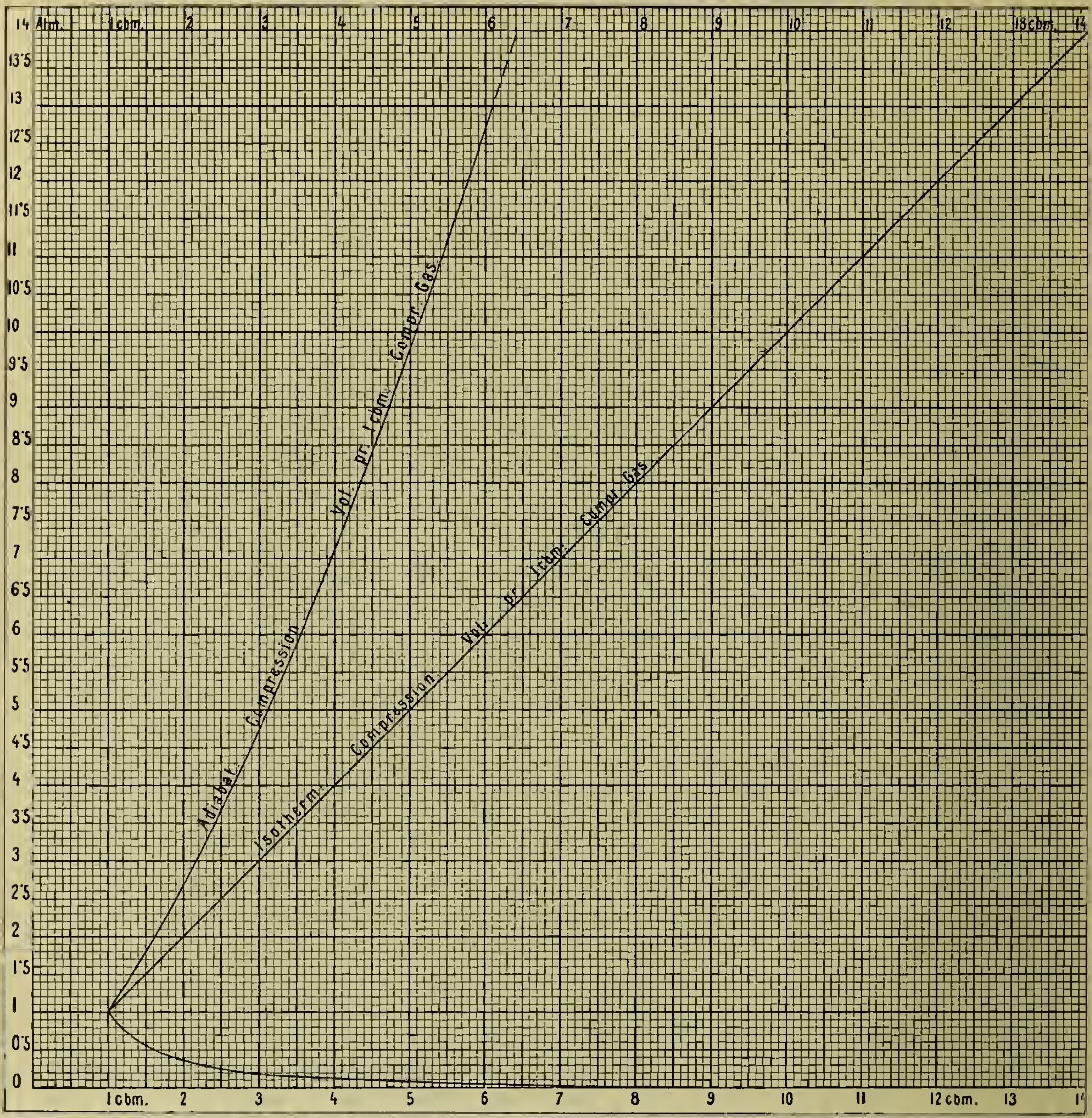
Curve 3 shows the heat produced during compression.

Example:

1 cbm. gas of 1 atmosphere and 273⁰ N abs. *isothermic* compressed to 7 atm. = 0·14 cbm.
1 » » » » » *adiabatic* » » 7 » = 0·256 »
1 » » » » » *isothermic* » » 7 » produces 45·2 cal.

which in *adiabatic compression* would increase the volume of the gas.

Diagram C.



Gompression of simple Gases, and of Compounds which have not been contracted by chemical Affinity.

Volume of gas of 1 atm. density and 273⁰ N abs. required to produce 1 cbm. af compressed gas.

Example:

1 cbm. gas of 7 atm. abs. requires 3·95 cbm. in *adiabatitc compression*
1 » » » 7 » » » 7·00 » » *isothermic compression.*

(Continued from pag. 24.)

Without rise of temperature, 1 cbm. gas of 1 atm. density, compressed to 10 atm., would form 0·1 cbm.; the absolute temperature of the compressed gas therefore must be as:

0·1 cbm. : 0·19684 cbm. = 273^0 N abs. : $537{\cdot}379^0$ N abs.

consequently, increase of temperature $537{\cdot}379^0$ N abs. — 273^0 N abs. = $264{\cdot}379^0$ N.

By calculating the temperature by formula:

$T_1 = T \times R^{5/17}$, we find

$R^{5/17} = 10^{5/17}$ = log. 0·29412 and
T = 273^0 N abs. = . 2·43616 consequently
T_1 = log. 2·73028 = $537{\cdot}379^0$ N abs.,

and increase of temperature = $537{\cdot}379^0$ N abs. — 273^0 N abs. = $264{\cdot}379^0$ N.

The quantity of heat develloped by the compression, consequently is = $264{\cdot}379^0$ N × 3/14 cal. = 56·6526 calors, and the dynamic energy required in the operation, and converted into heat is:

56·6526 cal. × 423·813 mkg. = 24010·108 mkg. One cbm. hydrogen, so compressed, consequently contains $\frac{1 \text{ cbm.}}{0{\cdot}19684 \text{ cbm.}}$ = 5·0802 cbm. of 1 atm. and 273^0 N abs., and weighs = 5·0802 cbm. × 5/56 kg. = 0·45350 kg.

§ 56. *One cbm. oxygen,* of 1 atm. and 273^0 N abs. compressed to 10 atm. will, like the hydrogen, be heated to $537{\cdot}379^0$ N abs.; 24010·108 mkg. of dynamic energy will be converted into 56·6526 calors of heat, and 5·0802 cbm. of 1 atm., density must be compressed to form 1 cbm. of 10 atm. density; but as 1 cbm. oxygen of 1 atm. and 273^0 N abs. weighs 10/7 kg., it follows that 1 cbm. of the compressed gas must weigh = 5·0802 cbm. × 10/7 kg. = 7·25743 kg. or exactly 16 times as much as 1 cbm. hydrogen of equal pressure and temperature. The case is similar for other simple gases, and for compounds, which have not been contracted by chemical affinity.

§ 57. **The heat generated** by *adiabatic* compression of compound gases, contracted by chemical affinity, is found by *dividing* the rise of temperature in compression of hydrogen, by the ratio of contraction of the gas in question, and the increase of volume, due to the heat generated, is found by *dividing* the increase of volume for hydrogen, by the ratio of contraction of the gas in question. — Example:

§ 58. *Carbon dioxide.* Ratio of contraction = 1·5.

One cbm. 1 atm. and 273^0 N abs., adiabatic compressed to 10 atm.

Increase of temperature for hydrogen $264{\cdot}379^0$ N, consequently

for carbon dioxide $\frac{264{\cdot}379^0 \text{ N}}{1{\cdot}5} = 176{\cdot}252^0$ N,
Initial abs. temperature 273·000 . abs., consequently
absolute temperature of compr. gas $449{\cdot}252^0$ N abs.
Increase of volume for hydrogen 0.09684 cbm., consequently
» for 0·1 cbm. compr. CO_2 $\frac{0{\cdot}09684}{1{\cdot}5}$ = 0·06456 cbm.
Volume of compr. gas not heated = 0·10000 «
Volume of compressed gas = 0·16456 cbm.

1 cbm. carbon dioxide of 10 atm. and $449{\cdot}252^0$ N abs. consequently contains

$$\frac{1\text{ cbm.}}{0{\cdot}16456}\text{ cbm.} = 6{\cdot}0767\text{ cbm. of 1 atm. and } 273^0\text{ N abs., and weighs}$$

$$6{\cdot}0767 \quad » \quad \times\ 110/56 \quad \text{kg.} = 11{\cdot}93637\text{ kg.}$$

§ 59. **Methane.** Ratio of contraction 2.5; 1 cbm. of 1 atm. and 273^0 N abs. compressed to 10 atm.

$$\text{Increase of temperature for methane } \frac{264{\cdot}379^0\text{ N}}{2{\cdot}5} = 105{\cdot}75150^0\text{ N.}$$

$$\text{Initial temperature} = 273{\cdot}0000^0 \text{ » abs.}$$

$$\textit{Temperature of compressed gas} = 378{\cdot}7515^0\text{ N abs.}$$

$$\text{Increase of volume } \frac{0{\cdot}09684\text{ cbm.}}{2{\cdot}5} = 0{\cdot}03874\text{ cbm.}$$

$$\text{Volume of compressed methane} = \underline{0{\cdot}10000 \text{ »}}$$

$$0{\cdot}13874\text{cbm.}$$

1 cbm. methane of 10 atm. and $378{\cdot}7515^0$ N abs. contains

$$\frac{1\text{ cbm.}}{0{\cdot}13874\text{ cbm.}} = 7{\cdot}20772\text{ cbm. of 1 atm. and } 273^0\text{ abs., and weighs}$$

$$7{\cdot}20772\text{ cbm.} \times 5/7\text{ kg.} = 5{\cdot}14837\text{ kg.}$$

§ 60. **Cooling of gas** *by adiabatic expansion.* Exactly as much heat, as generated by adiabatic compression, is absorbed by adiabatic expansion, and to find the decrease of temperature due to such expansion it is only required to reverse the calculations given above.

Tab. XII.

Adiabatic Compression

of Hydrogen and other simple Gases.

1 cbm. gas of 273^0 N abs. and 1 atmosphere pressure adiabatic compressed to:					To produce 1 cbm. compressed gas of 2—3—4 &c. atmospheres are required of *uncompressed* gas of 273^0 N abs. and atmospheric pressure:
2	atm.	produces	0·61308	cbm.	1·63111 cbm.
3	»	»	0·46047	»	2·17169 »
4	»	»	0·37585	»	2·66063 »
5	»	»	0·32107	»	3·11458 »
6	»	»	0·28230	»	3·54320 »
7	»	»	0.25320	»	3·94944 »
8	»	»	0·23042	»	4·33990 »
9	»	»	0·21204	»	4·71609 »
10	»	»	0·19684	»	5·08022 »
11	»	»	0 18403	»	5·43389 »
12	»	»	0·17307	»	5·77801 »
13	»	»	0·16350	»	6·11396 »
14	»	»	0·15522	»	6·44247 »
15	»	»	0·14785	»	6·76361 »
16	»	»	0·14126	»	7·07914 »
17	»	»	0·13534	»	7·38879 »
18	»	»	0·12999	»	7·69290 »
19	»	»	0·12512	»	7·99233 »
20	»	»	0·12067	»	8·31462 »
30	»	»	0·09064	»	11·03266 »
40	»	»	0·07400	»	13·51297 »
50	»	»	0·06325	»	15·82274 »
100	»	»	0.03870	»	25·80860 »

§ 61. **Isothermic compression** of gas converts dynamic energy into caloric (heat), similar as adiabatic compression, but as the heat generated, is immediately absorbed by cold water, or by other suitable means, neither the volume nor the pressure is increased by heat, and consequently less dynamic power is required, to effect the isothermic compression of 1 cbm. gas, then in adiabatic compression.

We only need to investigate the behaviour of hydrogen, and can then with ease solve similar problems relating to other gases.

In isothermic compression, hydrogen, and all other gases, obey the law of Mariotte; the pressure increases inversely, as the volume decreases, and volume × pressure (V × P) is in all cases = 1.

Tab. XIII.

§ 62. Isothermic Compression.

1 cbm. Gas of 1 Atm.	P	1	× V	1	=	VP	1	compressed to
9/10 cbm. produces 10/9 At.	»	9/10	× »	10/9	=	»	1	»
8/10 » » 10/8 »	»	8/10	× »	10/8	=	»	1	»
7/10 » » 10/7 »	»	7/10	× »	10/7	=	»	1	»
6/10 » » 10/6 »	»	6/10	× »	10/6	=	»	1	»
5/10 » » 10/5 »	»	5/10	× »	10/5	=	»	1	»
4/10 » » 10/4 »	»	4/10	× »	10/4	=	»	1	»
3/10 » » 10/3 »	»	3/10	× »	10/3	=	»	1	»
2/10 » » 10/2 »	»	2/10	× »	10/2	=	»	1	»
1/10 » » 10/1 »	»	1/10	× »	10/1	=	»	1	»

§ 63. If we plot these pressures into a diagram, (B. Curve 1) the curve connecting the ordinates of increasing pressure, will be a hyperbola, and the contents of the inclosed area, which represents the power spent in compressing the air, can with accuracy be computed, by using hyperbolic logarithms. The hyperbolic logarithm of the ratio of compression, multiplied by the initial pressure of the gas on the compressing piston, gives the caloric and dynamic work performed.

(Hyp. log. Tab. XI.)

§ 64. As shown in § 46, the compression of 1 cbm. of any gas, against 1 atm. resistance, is equal to $24^3/_8$ calors, consequently, the caloric work, required, to compress a gaseous substance from 1 to 2, 3, 4 &c. atmospheres pressure, is equal to $24^3/_8$ calors, multiplied by the hyperbolic logarithm (log. ε) of the ratio of compression, thus:

Example: 1 cbm. hydrogen of 273^0 N abs. and 1 atm. pressure, to be isothermic compressed to 10 atmospheres.

$$R = \frac{10 \text{ atm.}}{1 \text{ atm.}} = 10 . \quad \text{log.}\,\varepsilon \text{ of } 10 = \text{log.}\,\varepsilon\ 2{\cdot}3026.$$

$$24{\cdot}375 \text{ cal.} \times 2{\cdot}3026 = 56{\cdot}12588 \text{ calors.}$$

Example: 1 cbm. *oxygen* of 273^0 abs. and 1 atm., to be isothermic compressed to 6 atmospheres.

$$R = \frac{6 \text{ atm.}}{1 \text{ atm.}} = 6 . \quad \text{log.}\,\varepsilon \text{ of } 6 = \text{log.}\,\varepsilon\ 1{\cdot}7918.$$

$$24{\cdot}375 \text{ cal.} \times 1{\cdot}7918 = 43{\cdot}6751 \text{ calors.}$$

§ 65. The heat generated by the compression of the gas, must be instantly asorbed by cold water. The *dynamic* power required for the isothermic compression of 1 cbm. of gas, is for

Example 1. 56·12588 cal. × 423·813 mkg. = 23786·875 mkg., and for
» 2. 43·67513 » × 423·813 » = 18510·080 »

§ 66. As in isothermic compression, all the heat generated during the operation, is absorbed by cold water, it is evident that the calculations given above are applicable for *all*, simple, as well as compound gases.

Water, in the state of solid, liquid, steam, permanent gas (H_2O) decomposed into hydrogen and oxygen.

§ 67. By careful investigating the experiments of M. Regnault, the author has found some very remarkable and useful relations and proportions, which will be further explained and applied in the articles »*evaporation of water*« and »*combustion of gases*, viz:

1. That the total quantity of heat in 1 kg. of saturated steam, exactly increases by 0·3 calors, for every 1° N increase of temperature.
2. That, if. W. denotes the weight of 1 cbm. of steam in kg.
P. the absolute pressure of steam in atmospheres.
T. the absolute temperature of steam (°N abs.)

then is, according to M. Regnaults experiments, for all temperatures and pressures

$$\frac{W \times T}{P} = 219^3/_8 \qquad \text{f. inst.}$$

for 0·01 atm. $\dfrac{0{\cdot}00783 \text{ kg.} \times 280{\cdot}2^0 \text{ abs.}}{0{\cdot}01 \text{ atm.}} = 219^3/_8,$

for 0·1 atm. $\dfrac{0{\cdot}069 \text{ kg.} \times 319{\cdot}2^0 \text{ abs.}}{0{\cdot}1 \text{ atm.}} = 219^3/_8,$

for 1 atm. $\dfrac{0{\cdot}588 \text{ kg.} \times 373{\cdot}0^0 \text{ abs.}}{1 \text{ atm.}} = 219^3/_8,$

for 10 atm. $\dfrac{4{\cdot}841 \text{ kg.} \times 453{\cdot}3^0 \text{ abs.}}{10 \text{ atm.}} = 219^3/_8$ &c.

§ 68. If we work this out, through the whole range of M. Regnaults experiments, from 0·006 atmosphere to 28·88 atmospheres, we always get the same result, only with very trifling variations, which must be due to experimental errors. We therefore may conclude, that this holds good also for lower temperatures, and thus follows, that the evaporation of water at a vacuum, first begins at $219^3/_8{}^0$ N absolute temperature, but that below that temperature water does not evaporate, even in a perfect vacuum; as the following demonstation will prove:

According to § 11, saturated steam (aëriform water) of any temperature and pressure is exactly 9 times as heavy as hydrogen, at the same temperature and pressure, and consequently 1 cbm. of steam weighing 1/10000000 kg. must have the same pressure and temperature as 1 cbm. of hydrogen, weighing 1/90000000 kg.

According to § 9, does 1 cbm. of hydrogen of atmospheric pressure and 273^0 N abs. weigh = 5/56 kg. consequently 1 cbm. of 273^0 N abs. and
1/10000000 atm. = 5/560000000 kg. = 1/112000000 kg.

The weight of the gas *increases* by cooling at the same ratio as its temperature *decreases;* to increase its weight from 1/112000000 kg., to 1/90000000 kg. pr. 1 cbm. would require lowering its temperature as:
1/112000000 : 1/90000000 = 273^0 N abs. : $219^3/_8{}^0$ N abs.

At this temperature 1 cbm. hydrogen of 1/10000000 atm. consequently weighs 1/90000000 kg. and 1 cbm. steam of the same presssure 1/10000000 kg.

$\frac{\text{P}}{\text{W}}$ is in this case = 1, und consequently is

$$\text{T} = \frac{\text{Coeff. } 219^3/_8 \times 0{\cdot}0000001 \text{ atm.}}{0{\cdot}0000001 \text{ kg.}} = 219^3/_8{}^0 \text{ N absol.}$$

or *the temperature where in vacuum water can evaporate.*

§ 69. According to § 36—42 and Tab. VI is the specific heat of water-molecules pro 1 kg.

at constant pressure 17/30 cal. = 0·566666 cal.
» » volume 12/30 » = 2/5 = 0·400000 »

external work 5/30 cal. = 1/6 = 0·166666 cal.

At $219^3/_8{}^0$ N abs. (— $53^5/_8{}^0$ N) does 1 kg. solid water (ice) contain (see § 70) $219^3/_8{}^0$ abs. × 0·4 cal. = $87^3/_4$ calors (= 87·7500 cal.) To convert this 1 kg. ice of $219^3/_8{}^0$ abs. into liquid water of the like temperature, are, as proved by M. Regnault, 79·250 calors absorbed (made latent), and to evaporate this 1 kg. of liquid water of 273^0 N abs. in vacuum, are moreover made latent 8 × 79·25 cal. = 634 calors, *minus* 4/15 cal. for every 1^0 N absolute temperature of the steam, (which 4/15 cal. are converted into sensible heat (temperature); consequently requires the evaporation of 1 kg. liquid water of $219^3/_8{}^0$ N abs. absolute:

634·00 cal. — (4/15 cal. × $219^3/_8{}^0$ N abs.) = 634 — 58·50 cal. = 575 50 cal.

For 1 kg. water evaporated from 273^0 N abs.:

634·00 cal. — (4/15 cal. × 273^0 N abs.) = 634 — 72·80 » = 561·20 »

For 1 kg. water evaporated from 373^0 N abs.:

634·00 cal. — (4/15 cal. × 373^0 N abs.) = 634 — 99·466 » = 534·533 »

§ 70. Besides this quantity of heat, there are required, to evaporate 1 kg. of water:

1/9 cal. = 10/90 cal., for every 1^0 N absolute temperature of the steam produced, to overcome the external resistance of the atmosphere, or of the steam, generated in a closed boiler.
1/18 » = 5/90 » for every 1^0 N absolute temperature, to loosen the chemical affinity of the molecules, and
2/15 » = 12/90 » for every 1^0 N absolute temperature, to overcome the physical cohesion of the molecules.

Total 27/90 calors = 0·3 calors, must be supplied, for every 1^0 N absol., temperature of steam, besides the 634 — (4/15 T) calors latent, & 4/15 T calors of sensible heat, to produce 1 kg. of saturated steam = 634 + (0·3 T) calors.

§ 71. *Solid water* in a perfect vacuum, and at temperatures between absol. zero and $219\,^3/_8{}^0$ N absolute, is water substance at constant volume, and according to § 69 & 70, requires

4/15 = 24/90 calors of sensible heat, and
2/15 = 12/90 » of internal work,

Total 6/15 = 36/90 calors = 0·4 calors, to raise the temperature of 1 kg., 1^0 N. Similar circumstances prevail under atmospheric pressure, at temperatures between $219\,^3/_8{}^0$ N and 273^0 N and 273^0 N absolute, and therfor also 0·4 calors are sufficient, to heat 1 kg. 1^0 N.

§ 72. In a perfect or partial vacuum, and at temperatures, between $219\,^3/_8{}^0$ and 273^0 N absolute, the circumstances are different; the solid water will be converted into liquid, or into vapour, if the heat, nessecary for liquefying and vaporizing and the heat required to overcome external pressure, is imparted to it.

§ 73. *Liquid water* requires 1 calor pro 1 kg., to raise its temperature 1^0 N at atmospheric pressure, and not merely 0·4 calors pro 1 kg. like steam at constant volume, because, in heating 1 kg. of liquid water in an open vessel (at atmospheric pressure) heat is also required, to expand the volume of the water, to overcome atmospheric resistance against this expansion, to evaporate a portion of the water, during the operation of heating it, and by the vapour formed, to perform external caloric work against the pressure of the atmosphere. The sum total of these caloric processes, is the 1 calor, required to heat 1 kg. of liquid water 1^0 N. If we could heat water, *absolutely preventing its expansion and evaporation*, by hermetically inclosing it in a vessel of sufficcient strength, no doubt, 1 kg. of water will be heated 1^0 N by 0·4 calor.

§ 74. For heating solid water (ice) from absolute zero, up to $219\,^3/_8{}^0$ N abs. consequently pro 1 kg. are required:

$219\,^3/_8{}^0$ N × 0·4 calor = $87\,^3/_4$ calors = 87·7500 calors.

At this temperature ($219\,^3/_8{}^0$ N absolute) solid water may be converted into liquid water and into vapour, by adding (§ 69) respectively $79\,^1/_4$ and $575\,^1/_2$ calors which become latent, without raising the temperature.

For heating 1 kg. of solid water (ice) from absolute zero, up to 273^0 N abs. (0^0 N) are required: 273^0 N × 0·4 cal.	= 109·20 calors
Converting this 1 kg. of solid of 273^0 N abs. into liquid water of 273^0 N abs. makes latent	= 79·25 »
Total heat in 1 kg. of liquid water of 273^0 N abs. (0^0 N)	188·45 calors.

§ 75. *To convert this into vapour* of 273^0 N abs. is further required 8 × 79·25 cal. =	634 cal.	
minus: 4/15 cal. × 273^0 N = 72·8 cal. + (1/9 + 1/18) × 273^0 N = 45·5 »	27·30 »	= 606·70 calors.
Total heat in 1 kg. of vapour 273^0 N abs. (0^0 N)		= 795·15 calors.

§ 76. *To convert this into steam* of 373^0 N abs. (100^0 N) requires 0·3 cal. × 100^0 N	= 30·00 calors.
Total heat in 1 kg. of steam of 373^0 N abs. (100^0 N)	= 825·15 calors.

Diagram D.
§ 69—75.

Heat required

to evaporate 1 kg. solid Water of 0^0 N absolute.

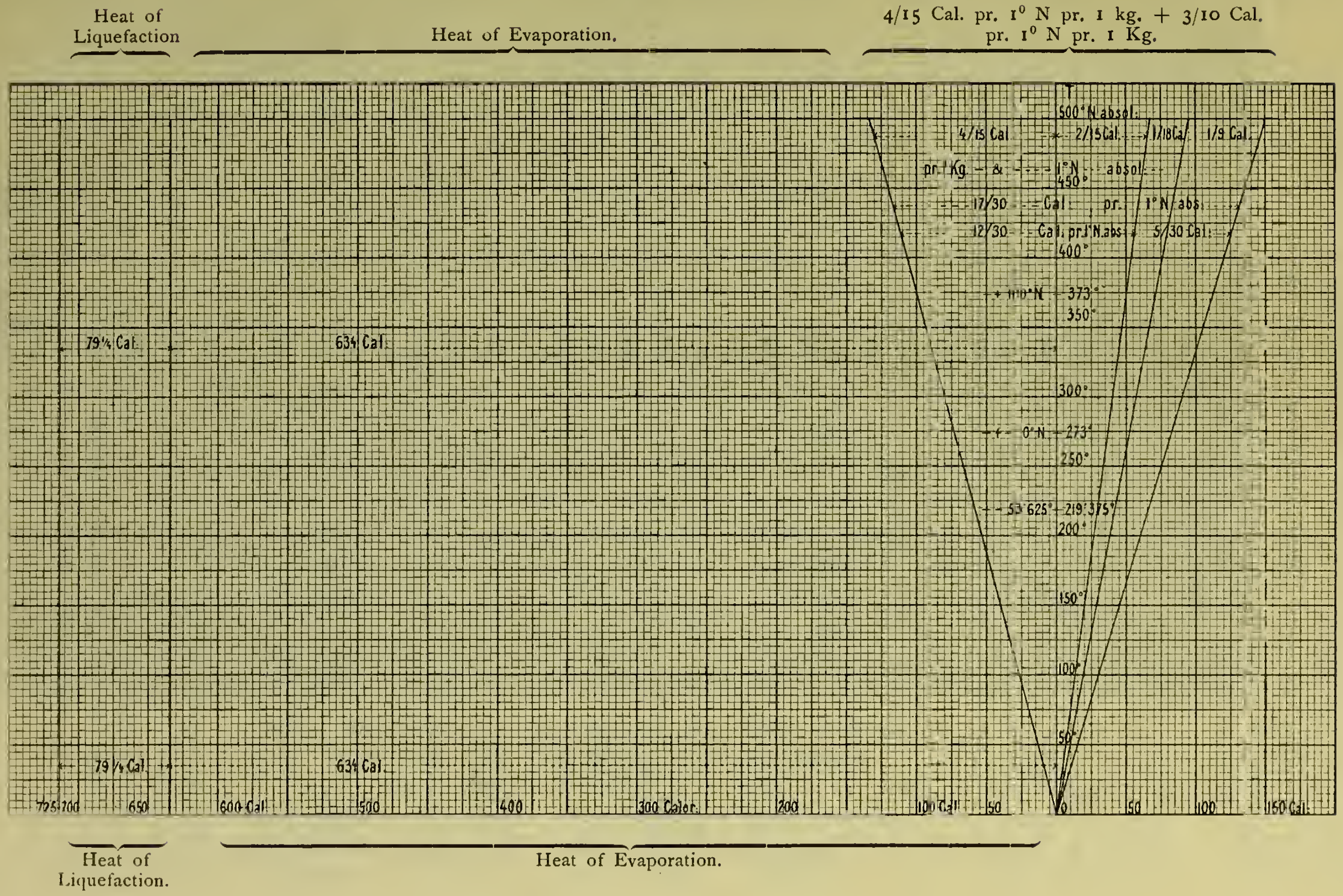
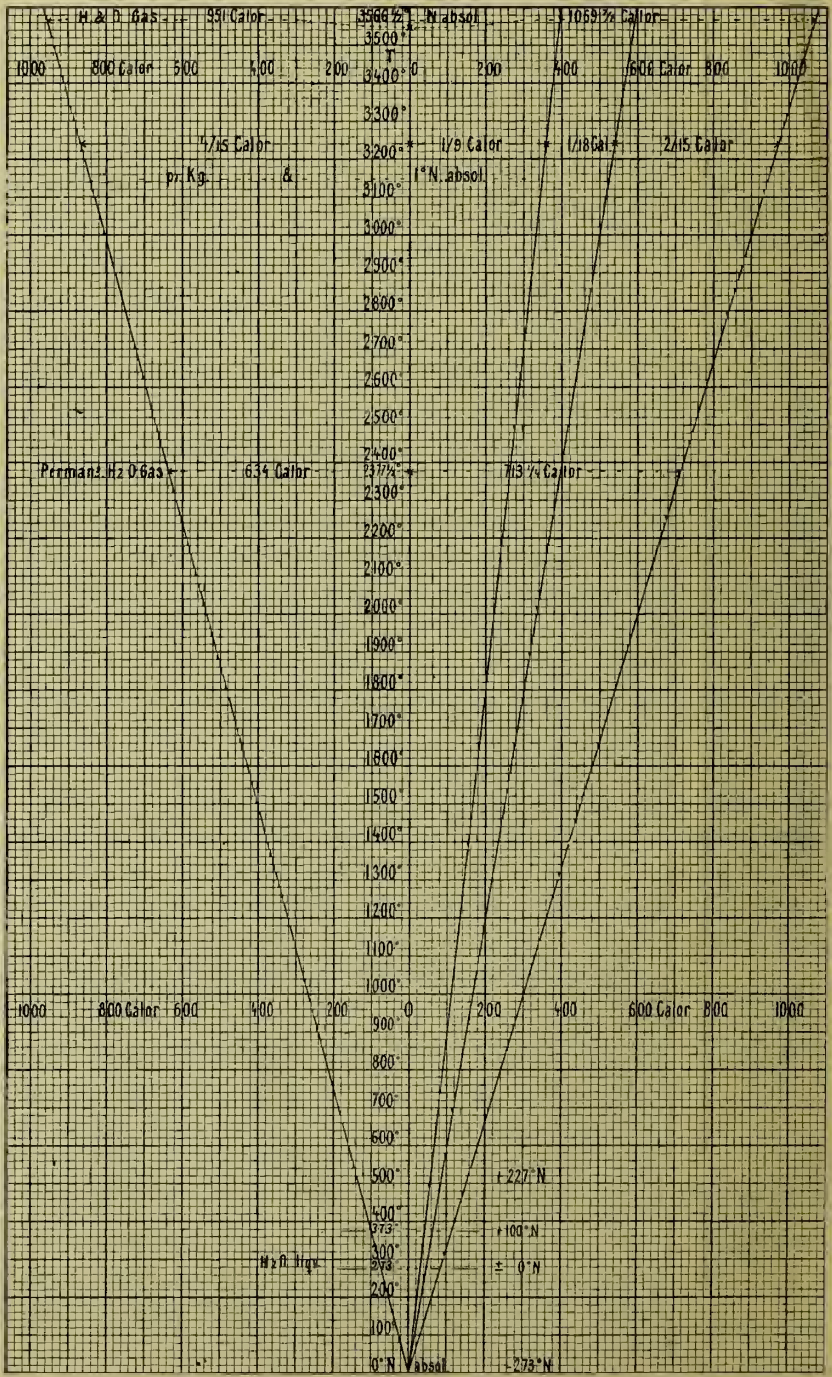


Diagram E.

Heat required.

To convert 1 kg. Ice of 0° N absolute, into liquid Water, Steam, H_2O Gas and H and O.



1 kg. ice of 0° N abs. heated to the temperature of decomposition 3566¼° N abs.

requires 4/15 Cal. × 3566¼° N = 951 Cal.

3/10 » × 3566¼° N = 1069⅞ »

decomposed into H & O requires 2 × 2020⅞ Cal. = 4041¾ Calors.

Permanent H_2O Gas (4/15 + 3/10 Cal.) × 2377½° N = 1347¼ do.

§ 77. *Water converted into H_2O gas.* As the $9 \times 79^1/_4$ cal. $= 713^1/_4$ cal. of latent heat, required for evaporating 1 kg. of solid water, decrease by 0·3 calor, for every 1^0 N of absolute temperature, and the $8 \times 79^1/_4$ cal. $= 634$ calors, required for evaporating 1 kg. of liquid water, decrease by 4/15 calor, for every 1^0 N of absolute temperature, it follows, that at a certain temperature, found by the proportion:

0·3 calor : $713^1/_4$ calors $= 1^0 : 2377^1/_2{}^0$ N absolute, or by the proportion
4/15 » : 634 » $= 1^0 : 2377^1/_2{}^0$ N absolute,

no further heat will be absorbed by internal resistance (or become latent); *the steam has been converted into a gas*, consisting of hydrogen and oxygen, chemically combined as H_2O. This H_2O gas, is the substance, which according to § 36—42 requires 17/30 calor, to heat 1 kg. at constant pressure 1^0 N. In heating 1 kg. of solid water, of 0^0 N absolute up to $2377^1/_2{}^0$ N absolute, no heat is absorbed as latent, but all the heat applied, is converted into sensible heat or temperature, consequently, pro 1 kg. of solid water are required:

$2377^1/_2{}^0$ N absolute $\times$ 17/30 calors $= 1347^1/_4$ calors
which is equal to
$(1 + 8 + 8) \times 79^1/_4$ cal. $= 1347^1/_4$ »

§ 78. **Water decomposed into simple hydrogen and oxygen gas.** If we heat 1 kg. of solid water, of 0^0 N absolute, to $1^1/_2 \times 2377^1/_2{}^0$ N absol. $= 3566^1/_4{}^0$ abs., we have brought it to the temperature, where the molecules of H_2O decompose into simple hydrogen and oxygen gas. To heat 1 kg. of solid water to this temperature, are required:

$3566^1/_4{}^0$ N abs. $\times$ 17/30 cal. $= 2020^7/_8$ calors, but in order, actually to split the H_2O molecules into simple hydrogen and oxygen gas, of $3566^1/_4{}^0$ N absolute temperature, we require; pro 1 kg.

$2 \times 2020^7/_8$ cal. $=$ $4041^3/_4$ calors
which is equal to
$3 \times (1 + 8 + 8) \times 79^1/_4$ cal. $= 3 \times 17 \times 79^1/_4 = 4041^3/_4$ calors.

§ 79. By this operation, the 1 kg. of ice of 0^0 N absolute, is dissolved into 1/9 kg. of hydrogen and 8/9 kg. of oxygen, which at that temperature ($3566^1/_4{}^0$ N absolute) are $=$ 634/39 cbm. hydrogen, and 317/39 cbm. oxygen $=$ total 951/39 cbm. $= 24^5/_{13}$ cbm. of simple gases, of atmospheric pressure.

§ 80. As dissolving 1 kg. of ice of 0^0 N absolute temperature, into its components, requires $4041^3/_4$ calors, it follows, that the combustion of 1/9 kg. of hydrogen, with 8/9 kg. of oxygen (which form 1 kg. of water) must likewise devellop $4041^3/_4$ calors, and consequently, the combustion of 1 kg. of hydrogen, with 8 kg. of oxygen, forming 9 kg. of water, will produce:

9 kg. $\times$ $4041^3/_4$ cal. $=$ 36375·75 calors total heat
9 kg. of water of 273^0 N abs. contain $9 \times 188.45 =$ 1696·05 » consequently

1 *kg. hydrogen, burnt with oxygen produces* 34679·70 calors, if the initial temperature of the gases has been 273^0 N absolute (0^0 N) and the products of combustion are cooled down to that temperature; and the *temperature of combustion of hydrogen with oxygen is* $3566^1/_4{}^0$ N absolute and

$3566^1/_4{}^0$ N — 273^0 N $=$ × $3293^1/_4{}^0$ N.

§ 81. **Pressure exerted by freezing water.** Distilled water at 4^0 N = 277^0 N absol., its point of greatest density, weighs 1000 kg. pro 1 cbm.; if cooled down to 0^0 = 273^0 N absol., without congealing, it would decrease in volume and increase in specific gravity and judging from the contraction, in cooling water from higher temperatures down to 4^0 N, we find, that 1 cbm. liquid water of 0^0 N = 273^0 N abs. would weigh 1001·7029 kg., and that 1000 kg. liquid water, of 273^0 N abs. = 0^0 N would be = 0·9983 cbm. The specific gravity of ice, from distilled water, is = 0·926, consequently 1000 kg. ice are = $\frac{1000 \text{ kg.}}{0{\cdot}926 \text{ kg.}}$ = 1·0799 cbm., and the increase of volume as 0·9983 cbm. : 1·0799 cbm. = 1·00 : 1·0817 cbm. When 1 kg. of water is converted into ice, 79·25 calors are set free without raising the temperature; the 79·25 calors generate $\frac{79{\cdot}25 \text{ cal.}}{606{\cdot}70 \text{ cal.}}$ = 0·1306 kg. steam of 273^0 N abs., which at this temperature is = 0·16252 cbm. of atmospheric pressure pro 1 kg. congealing water, consequently: 0·16252 cbm. × 1000 kg. = 162·52 cbm. steam of 1 atm. pro 1 cbm. congealing water.

The increase of volume, of 1 cbm. of water freezing, is as shown:

1·0817 cbm. — 1·000 cbm. = 0·0817 cbm. and consequently the 162·52 cbm. steam of atmospheric pressure and 273^0 N abs., must in the process of congealing, be *isothermic* compressed to 0·0817 cbm. and consequently, *the pressure exerted by the freezing water*, must be

$$\frac{162{\cdot}52 \text{ cbm.}}{0{\cdot}0817 \text{ cbm.}} = 1989 \text{ atmospheres.}$$

Water hermetically inclosed in a vessel, of sufficient strength, to resist the pressure exerted, without expansion, remains liquid at — 24^0 C (249^0 absolute) as proved by M. Bousingaults experiment, and probably it remains liquid at all lower temperatures, down to $219^3/_8{}^0$ N absolute (— $53^5/_8{}^0$N) if expansion could be absolutely prevented.

§ 82. **Evaporation of Water. Steam.** If water is heated in a hermetical closed vessel, the steam produced is under the condition of »*constant volume*«. In the working of steam boilers, this is only the case, while a boiler is started or »fired up« or during interruptions of the working; in boilers in regular work, the steam flows out, as fast as it is produced, and the quantity of water in the boiler, and the quantity of heat, stored up in that water, remains unaltered, although new water is fed into the boiler, to make up for the quantity, passing off as steam. The quantity of heat required, to evaporate, say 1 kg. of water, and generate 1 kg. of steam, and which passes away with that 1 kg. of steam, has only passed from the fire, through the water stored up in the boiler, and to find the quantity of heat expended, to produce one kg. of steam of any desired density, we have only to ascertain, how much heat that one kg. of steam of the desired pressure, is capable to contain.

The specific heat of water at various temperatures, has no influence in the question, and has only to be considered, if we were to ascertain the exact quantity of heat, required, to »fire up« a boiler. In a boiler in regular working, the condition therefore is, »*evaporation at constant pressure*«, just the same, as evaporation in an open vessel would be, if the atmosphere of our globe had the pressure or density existing in a steam boiler, and *the temperature of saturated steam in a boiler, is the temperature, at which water would boil in an open vessel, and in an atmosphere, equal in pressure or density to that in the boiler.*

§ 83. Water can evaporate at any temperature, down to $219^3/_8\,^0$ N abs., and form steam of a pressure and density, corresponding to the temperature at which the evaporation takes place; it is therefore advisable and convenient, to consider the process of evaporation from absolute zero (— 273^0 N).

§ 84. Steam is a compound substance, consisting by weight of 1/9 part of hydrogen and 8/9 part of oxygen gas, or by volume, of 2 volumes of hydrogen and 1 volume of oxygen, which 3 volumes of gas in combining have contracted into 2 volumes of steam of equal pressure as the component gases. Although steam for practical purposes, is generated by the evaporation of water, it is useful, for the investigation of its properties, to consider the production of steam by combination of hydrogen and oxygen. By this means, we are able, in a very simple way, and to the highest degree of accuracy, to calculate the volume, weight, and pressure of steam, due to any temperature, — the temperature due to any pressure, the remarkable relation, between volume, pressure and absolute temperature of steam, &c.

§ 85. According to § 9, 1 cbm. hydrogen of 273^0 N absolute and atmospheric density, weighs 5/56 kg., and 1 cbm. oxygen of the same temperature and density 80/56 kg. At equal temperatures, the weight of gases is in proportion to their pressure or density, consequently, at 273^0 N absolute:

Tab. XIV.

						Hydrogen.	*Oxygen.*
1	cbm.	of	1/1000	atmosphere weighs	=	5/56000 kg.	80/56000 kg.
1	»	»	4·2/1000	»	=	3/8000 -	48/8000 -
1	»	»	1/100	»	=	5/5600 -	80/5600 -
1	»	»	1/10	»	=	5/560 -	80/560 -
1	»	»	1	»	=	5/56 -	80/56 -
1	»	»	10	»	=	50/56 -	800/56
1	»	»	100	»	=	500/56 -	8000/56 -

and from these data, we find the *weight of 1 cbm. of steam, of 273^0 N absol.* as follows:

§ 86.

1 cbm. hydrogen of 1/1000 atm. & 273^0 N abs. = 5/56000 kg. combined with
$^1/_2$ » oxygen à 80/56000 kg. = 40/56000 » forms

1 cbm. steam of 1/1000 atm. & 273^0 N abs. = 45/56000 kg. = 9/11200 kg. &
1 kg. » » » » = 56000/45 cbm. = 11200/9 cbm.

1 cbm. hydrogen of 4·2/1000 atm. & 273^0 N abs. = 3/8000 kg. combined with
$^1/_2$ » oxygen à 48/8000 kg. = 24/8000 » forms

1 cbm. steam of 4·2/1000 atm. & 273^0 N abs. = 27/8000 kg. and
1 kg. » » » = 8000/27 cbm.

1 cbm. hydrogen of 1/100 atm. & 273^0 N abs. = 5/5600 kg. combined with
$^1/_2$ » oxygen à 80/5600 kg. = 40/5600 - forms

1 cbm. steam of 1/100 atm. & 273^0 N abs. = 45/5600 kg. and
1 kg. » » » = 5600/45 cbm. = 1120/9 cbm.

1 cbm. hydrogen of 1/10 atm. & 273^0 N abs. = 5/560 kg. combined with
$^1/_2$ » oxygen à 80/560 kg. = 40/560 » forms

1 cbm. steam of 1/10 atm. & 273^0 N abs. = 45/560 kg. and
1 kg. » » » = 560/45 cbm. = 112/9 cbm.

1 cbm. hydrogen of 1 atm. & 273^0 N abs. = 5/56 kg. combined with
$^1/_2$ » oxygen à 80/56 kg. = 40/56 » forms

1 cbm. steam of 1 atm. & 273^0 N abs. = 45/56 kg. and
1 kg. » » » = 56/45 cbm. (1000kg. = $\frac{56000}{45}$ = $1244^4/_9$cbm.)

1 cbm. hydrogen of 10 atm. & 273^0 N abs. = 50/56 kg. combined with
$^1/_2$ » oxygen à 800/56 kg. = 400/56 » forms

1 cbm. steam of 10 atm. & 273^0 N abs. = 450/56 kg. and
1 kg. » » » = 56/450 cbm.

1 cbm. hydrogen of 100 atm. & 273^0 N abs. = 500/56 kg. combined with
$^1/_2$ » oxygen à 8000/56 kg. = 4000/56 » forms

1 cbm. steam of 100 atm. & 273^0 N abs. = 4500/56 kg. and
1 kg. » » » = 56/4500 cbm.

§ 87. **The steam** *expands at constant pressure* in *direct* proportion as its *absolute temperature;* as the temperature of saturated steam of atmospheric pressure is = 100^0 N (373^0 N abs.), so is the volume of 1 kg. of such steam, which, as shown, at 273^0 N absolute is = 56/45 cbm.

$$\text{at } 373^0 \text{ N abs.} = \frac{56 \times 373^0 \text{ N abs.}}{45 \times 273^0 \text{ N abs.}} = \frac{20888}{12285} = \frac{2984}{1755} \text{ cbm.} = 1{\cdot}70028 \text{ cbm.}$$

$$\text{and 1 cbm. weighs} = \frac{1755}{2984} \text{ kg.} = 0{\cdot}5881387 \text{ kg.}$$

§. 88. The temperature at which 1 cbm. steam of normal atmospheric pressure weighs 1 kg., and where consequently 1 kg. steam of atmospheric pressure = 1 cbm., is found by proportion:

56/45 cbm. : 45/45 cbm. = 273^0 N abs. : $1755/8^0$ = $219^3/_8{}^0$ N. = $219{\cdot}375^0$ N abs., consequently weighs at $219^3/_8{}^0$ N abs.

Tab. XV.

1	cbm.	steam of	1/1000	atm.	=	1/1000	kg. and	1	kg. is	=	1000	cbm.
1	»	»	1/100	»	=	1/100	»	1	»	=	100	»
1	»	»	1/10	»	=	1/10	»	1	»	=	10	»
1	»	»	1	»	=	1	»	1	»	=	1	»
1	»	»	10	»	=	10	»	1	»	=	0,1	»
1	»	»	100		=	100	»	1	»	=	0,01	»

§ 89. The *real weight* of 1 cbm. saturated steam of the temperature due to its pressure is found by the equation:

(1) $T : (1755/8)^{0}$ N abs. $= w : W$.

where T denotes the absolute temperature due to the pressure
w the weight due to pressure at $219{\cdot}375^{0}$ N absolute.
W the weight due to pressure at temperature T,

and the *real volume* (cbm. pro 1 kg.) of saturated steam, is found by equation:

(2) $(1755/8)^{0}$ N abs. $: T = v : V$.

where v denotes the volume due to the required pressure at $219{\cdot}375^{0}$ N abs.
and V the volume due to temperature T.

The Boiling Temperature of Water.

§ 90. Water, as demonstrated in § 66 & 67 does not evaporate at lower temperature than $219\,{}^{3}/_{8}{}^{0}$ N absolute. At this temperature, the pressure of vapour is = 0.

Tab. XVI.

	1				2	3	4		5	
At	0·0000001	atm. abs.	pressure is the	temperature					$220\,{}^{13}/_{27}{}^{0}$	N abs.
»	0·000001	»	the temperature	rises	$128/27^{0}$ N	$\times 1{\cdot}5^{0} =$	$4\,{}^{20}/_{27}{}^{0}$ N	to	$225\,{}^{2}/_{9}$	»
»	0·00001	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{1} =$	$7\,{}^{1}/_{9}$	»	$232\,{}^{1}/_{3}$	»
»	0·0001	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{2} =$	$10\,{}^{2}/_{3}$	»	243	»
»	0·001	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{3} =$	16	»	259	»
»	0·01	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{4} =$	24	»	283	»
»	0·1	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{5} =$	36	»	319	»
»	1·0	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{6} =$	54	»	373	»
»	10·0	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{7} =$	81	»	454	»
»	100·0	»	»	»	$128/17^{0}$	$\times 1{\cdot}5^{8} =$	$121\,{}^{1}/_{2}$	»	$575\,{}^{1}/_{2}$	»
»	1000·0	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{9} =$	$182\,{}^{1}/_{4}$	»	$757\,{}^{3}/_{4}$	»
»	10000·0	»	»	»	$128/27^{0}$	$\times 1{\cdot}5^{10} =$	$273\,{}^{3}/_{8}$	»	$1031\,{}^{1}/_{8}$	»

§ 91. For the pressures between those given in Tab. XVI we find the boiling temperatures, and for given temperatures the pressures of steam due to them, by means of Tab. XVII.

If P denotes any one of the pressures in table XVI,
V, » the volume of steam (cbm. pr. 1 kg.) due to that pressure,
T » the absolute temperature, due to pressure P,
T, » » » » » » » 10 P.
T,, required abs. temperature of steam of pressure x . P
t difference between T and T,
t, » » T and T,,
S ratio of rise of temperature for x . P
S, » » » » » » 10 P then is:

Tab. XVII.

§ 92. *Pressure 1 P.*	*Volume 1 V.*		*Ratio of rise of temperature for x . P.*		
2 P	1/2 =	1260/2520			1260
3 P	1/3 =	840/ »	1260 +	840 =	2100
4 P	1/4 =	630/ »	2100 +	630 =	2730
5 P	1/5 =	504/ »	2730 +	504 =	3234
6 P	1/6 =	420/ »	3234 +	420 =	3654
7 P	1/7 =	360/ »	3654 +	360 =	4014
8 P	1/8 =	315/ »	4014 +	315 =	4329
9 P	1/9 =	280/ »	4329 +	280 =	4609
10 P	1/10 =	252/ »	4609 +	252 =	4861 for 10 P.
1.	2.	3.	4.	5.	6.

and we find t, by proportion

$$S_{,} : S = t : t_{,} \quad \text{and}$$

$$T_{,,} = T + t_{,} \ . -$$

§ 93. *Example.* *Required* the absolute temperature for 0·6 atm. pressure:

At P = 0·1 atm. is T = 319^0 N abs.
P = 1·0 » » $T_{,} = 373^0$ »

difference t = 54^0 N

$S_{,} : S = t : t_{,}$, consequently (Tab. XVII.)

$4861 : 3654 = 54^0 \text{ N} : 40{\cdot}592^0$ N rise of temperature

and $T_{,,} = 319^0$ N abs. + $40{\cdot}592^0$ N = $359{\cdot}592^0$ N abs.

Required the abs. temperature for 9 atmospheres.

At P = 1 atm. is T = 373^0 N abs.
P = 10 » is $T_{,} = 454^0$ N »

difference t = 81^0 N

$4861 : 4609 = 81^0 \text{ N} : 76{\cdot}801^0$ rise of temperature

and $T_{,,} = 373^0$ N abs. + $76{\cdot}801^0$ N = $449{\cdot}801^0$ N abs.

Required the absolute temperature for 20 atmospheres.

At P = 10 atm. is T = 454^0 N abs.
P = 100 » $T_{,} = 575{\cdot}5^0$ N »

difference t = $121{\cdot}5^0$ N

$4861 : 1260 = 121{\cdot}5^0 \text{ N} : 31{\cdot}50^0$ N rise of temperature.

and $T_{,,} = 454^0$ N abs. + $31{\cdot}50^0$ N = $485{\cdot}50^0$ N abs.

Required the absolute temperature for 40 atmospheres.

At P = 10 atm. is T = 454^0 N abs.
P = 100 » $T_{,} = 575{\cdot}5^0$ N abs.

difference t = $121{\cdot}5^0$ N.

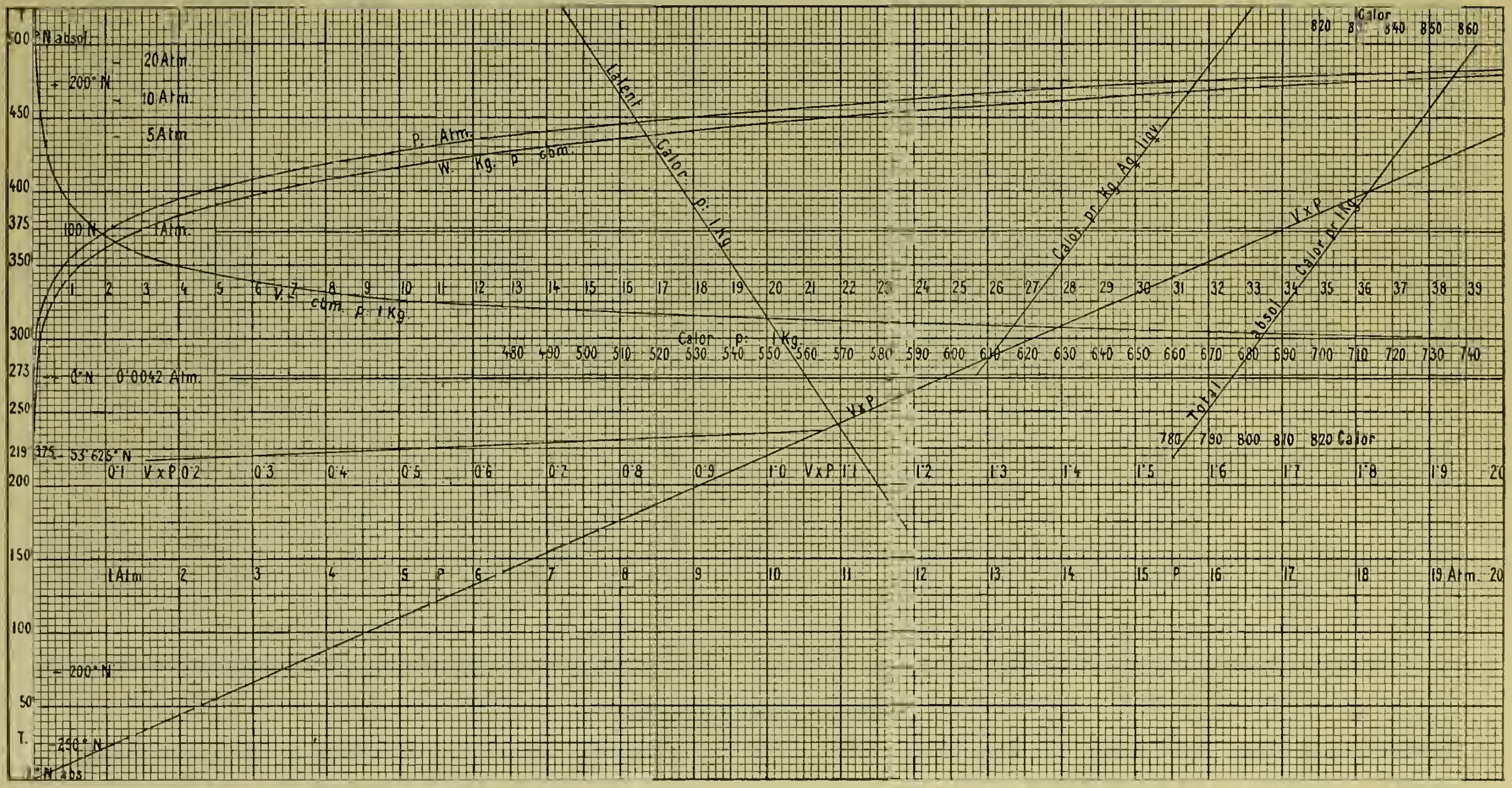
$4861 : 2730 = 121{\cdot}5^0 \text{ N} : 68{\cdot}24^0$ N rise of temperature

and $T_{,,} = 454^0$ N abs. + $68{\cdot}24^0$ N = $522{\cdot}24^0$ N abs.

Diagram F.
§ 95—102.

Evaporation of 1 kg. Ice and liquid Water from 0° N absolute.

Weight of 1 cbm.; Volume of 1 kg. saturated Steam.
Calors in 1 cbm. steam from 0 to 20 Atmospheres.



Explanation of Diagram pag. 49.

Tab. XIX a.

§ 97—101.

Temperature, Pressure, Volume, Weight, V × P, and Quantity of Heat pro one Kilogramm of saturated Steam.

Pressure absolute Atmospheres. P.	Boiling Temperature.		To raise the temperature of Steam, at const. Pressure. 8/30 T. Cal.	Latent Heat to overcome			Latent Heat of		Total Heat in 1 kg. of Steam of		Volume of 1 kg. of Steam. cbm. V.	V × P.
	Absolute T.	Deg. N. t.		Affinity of O. & H. 4/30 T. Cal.	External Pressure. 1/9 T. Cal.	Cohesion. of Molecul. 1/18 Cal.	Liquefaction. 79·25 Calors.	Evaporation 634—4/15 T. Calors.	Solid Water. Calors. 634 + 79·25 + 0·3 T.	Liquid Water. Calors. 634 + 0·3 T — (72·8 + 36·4 + 79·25) = 634 + 0·3 T) — 188·45		
1	2	3	4	5	6	7	8	9	10	11	12	13
0·000000	219·375 ° N	— 53·625 ° N	58·500	29·250	24·375	12·1875	79·25	575·500	779·062		0·00000	
0·000001	225·222	— 47·777	60·060	30·030	25·025	12·5125	79·25	573·940	780·817		1026653·000	1·02665
0·00001	232·333	— 40·666	61·956	30·978	25·815	12·9075	79·25	572·040	782·954		105910·000	1·05910
0·0001	243·000	— 30·000	64·800	32·400	27·000	13·5000	79·25	569·200	786·150		11076·900	1·10769
0·0002	247·147	— 25·853	65·908	32·954	27·461	13·7305	79·25	568·092	787·394		5632·980	1·12660
0·0003	249·912	— 23·088	66·643	33·322	27·768	13·8840	79·25	567·357	788·224		3797·469	1·13924
0·0004	251·996	— 21·004	67·199	33·599	28·000	14·0000	79·25	566·801	788·849		2871·749	1·14869
0·0005	253·649	— 19·351	67·640	33·820	28·183	14·0915	79·25	566·360	789·345		2312·469	1·15623
0·0006	255·027	— 17·973	68·007	34·004	28·336	14·1680	79·25	565·903	789·785		1937·526	1·16252
0·0007	256·212	— 16·788	68·323	34·162	28·468	14·2340	79·25	565·677	789·114		1664·384	1·16507
0·0008	257·250	— 15·750	68·599	34·300	28·583	14·2915	79·25	565·401	790·425		1465·812	1·17465
0.0009	258·171	— 14·829	68·845	34·423	28·686	14·3430	79·25	565·155	790·701		1307·609	1·17465
0·0010	259·000	— 14·000	69·066	34·533	28·778	14·3890	79·25	564·934	790·950		1180·062	1·18006
0 0020	265·221	— 7·779	70·726	35·363	29·496	14·7345	79·25	563·274	792·816		604·492	1·20898
0·0030	269·368	— 3·632	71·832	35·916	29·930	14·9150	79·25	562·168	794·060		410·653	1·23196
0·0040	272·494	— 0·506	72·665	36·333	30·277	15·1385	79·25	561·335	794·998		310·543	1·24217
0·0042	273·000	± 0·000	72·800	36·400	30·333	15·1666	79·25	561·200	795·150	Col. 10 — 188·45 606·700	296·296 *)	1·24444
0 005	274·973	+ 1·973	73·326	36·663	30·553	15·2765	79·25	560·674	795·742	607·392	250·688	1·25344
0·006	277·041	+ 4·041	73·878	36·939	30·782	15·3910	79·25	560·122	796·362	607·912	210·407	1·26244
0·007	278·818	+ 5·818	74·352	37·176	30·980	15·4900	79·25	559·648	796·895	608·445	181·567	1·27097
0·008	280·374	+ 7·374	74·766	37·383	31·153	15·5765	79·25	559·234	797·362	608·912	159·757	1·27806
0·009	281·756	+ 8·756	75·135	37·567	31·305	15·6525	79·25	558·865	797·777	609·327	142·706	1·28435
0·01	283·000	+ 10·000	75·466	37·733	31·444	15·7222	79·25	558·534	798·150	610·700	129·003	1·29003
0·02	292·331	+ 19·331	77·954	38·977	32·481	16·2405	79·25	556·046	800·049	612·499	66·628	1·33256
0·03	298·552	+ 25·552	79·612	39·806	33·172	16·5860	79·25	554·388	802·816	614·366	45·499	1·36497
0·04	303·218	+ 30·218	80·858	40·429	33·691	16·8455	79·25	553·142	804 215	615·795	34·555	1·38220

*) $\frac{8000}{27}$

1	2	3	4	5	6	7	8	9	10	11	12	13
0·05	306·960° N	+ 33·960° N	81·856	40·928	34·107	17·0535	79·25	552·184	805·338	616·888	27·985	1·39925
0·06	310·061	+ 37·061	82·682	41·341	34·451	17·2255	79·25	551·318	806·268	617·818	23·556	1·41336
0.07	312·727	+ 39·727	83·392	41·696	34·747	17·3735	79·25	550·608	807·068	619·618	20·365	1·42555
0·08	315·060	+ 42·060	84·014	42·007	35·006	17·5030	79·25	549·986	807·768	619·318	17·952	1·43616
0·09	317·134	+ 44·134	84·568	42·284	35·237	17·6185	79·25	549·432	808·390	620·940	16·966	1·44594
0·1	319·000	+ 46·000	85·066	42·533	35·444	17·7222	79·25	548·934	808·950	620·500	14·541	1·4541
0·2	332·997	+ 59·997	88·800	44·400	37·000	18·5000	79·25	546·200	813·149	624·699	7·590	1·5180
0·3	341·328	+ 68·328	91·020	45·510	37·925	18·9625	79·25	542·980	815·648	627·189	5·186	1·5558
0·4	349·327	+ 76·327	93·154	46·577	38·814	19·4070	79·25	540·846	818·048	629·598	3·981	1·5924
0·5	354·940	+ 81·940	94·652	47·326	39·438	19·7190	79·25	539·348	819·732	631·282	3·236	1·6180
0.6	359·592	+ 86·567	95·892	47·946	39·955	19·9775	79·25	538·108	821·128	632·678	2·732	1·6392
0·7	363·591	+ 90·591	96·958	48·479	40·399	20·1995	79·25	537·042	822·327	633·877	2·368	1·6567
0·8	367·091	+ 94·091	97·892	48·946	40·788	20·3940	79·25	536·108	823·377	634·927	2·092	1·6736
0·9	370·201	+ 97·201	98·720	49·360	41·133	20·5665	79·25	535·280	824·310	635·860	1·875	1·6875
1·0	373·000	+ 100·000	99·466	49·733	41·444	20·7222	79·25	534·534	825·150	636·700	1·7002849 *)	1·7002849
1·1	375·854	+ 102·854	100·228	50·144	41·762	20·8810	79·25	533·722	826·006	637·556	1·557	1·7127
1·2	378·471	+ 105·471	100·924	50·462	42·052	21·0260	79·25	533·076	826·791	638·341	1·438	1·7256
1·3	380·887	+ 107·887	101·570	50·785	42·321	21·1605	79·25	532·430	827·516	639·066	1·335	1·7355
1·4	383·129	+ 110·129	102·168	51·084	42·570	21·2850	79·25	531·832	828·189	639·739	1·247	1·7458
1·5	385·223	+ 112·223	102·728	51·364	42·803	21·4015	79·25	531·272	828·817	640·367	1·171	1·7565
1·6	387·186	+ 114 186	103·250	51·625	43·021	21·5105	79·25	530·750	829·406	640·956	1·103	1·7648
1·7	389·033	+ 116·033	103·742	51·871	43·226	21·6130	79·25	530·258	829·960	641·510	1·043	1·7731
1·8	390·777	+ 117·777	104·208	52·104	43·420	21·7100	79·25	529·792	830·483	642·033	0·988	1·7684
1·9	392·431	+ 119·431	104·648	52·324	43·603	21·8015	79·25	529·352	830·979	642·529	0·941	1·7879
2·0	393·996	+ 120·996	105·064	52·532	43·777	21·8885	79·25	528·936	831·449	642·999	0·898	1·7960
2·5	401·685	+ 128·685	107·116	53·558	44·632	22·3160	79·25	526·884	833·755	645·305	0·732	1·8300
3·0	407·993	+ 134·993	108·800	54·400	45·333	22·6665	79·25	525·200	835·648	647·198	0·620	1·8597
3·5	413·637	+ 140·637	110.304	55·152	45·960	22·9800	79·25	523·696	837·341	648·891	0·539	1·8865
4·0	418·491	+ 145·491	111·598	55·799	46·499	23·2495	79·25	522·402	838·797	650·347	0·477	1·9080
4·5	422·922	+ 149·922	112·778	56·389	46·991	23·4955	79·25	521·222	840·127	651·677	0·428	1·9260
5·0	426·889	+ 153·889	113·834	56·917	47·432	23·7160	79·25	520·166	841·317	652·867	0·389	1·9460
5·5	430·568	+ 157·568	114·818	57·409	47·841	23·9205	79·25	519·182	842·420	653·970	0·357	1·9635
6·0	433·888	+ 160·888	115·704	57·852	48·210	24·1050	79·25	518·296	843·416	654·966	0·330	1·9776
6·5	437·002	+ 164·002	116·534	58·267	48·556	24·2780	79·25	517·466	844·351	655·901	0·306	1·9916
7·0	439·886	+ 166·886	117·302	58·651	48·876	24·4380	79·25	516·698	845·216	656·766	0·286	2·0048
7·5	442·598	+ 169·598	118·028	59·014	49·178	24·5890	79·25	515·972	846·029	657·579	0·269	2·0175
8·0	445·135	+ 172·135	118·702	59·351	49·459	24·7295	79·25	515·298	846·790	658·340	0·254	2·0292
8·5	447·175	+ 174·175	119·246	59·623	49·686	24·8430	79·25	514·754	847·402	658·952	0·240	2·0396
9·0	449·801	+ 176·801	119·948	59·974	49·978	24·9390	79·25	514·052	848·190	569·740	0·228	2·0502
9·5	451·958	+ 178·958	120·524	60·262	50·218	25·1090	79·25	513·476	848·837	660·887	0·217	2·0596
10·0	454·000	+ 181·000	121·066	60·533	50·444	25·2225	79·25	512·934	849·450	661·000	0·207	2·0696
11.0	458·282	+ 185·282	122·208	61·104	50·920	25·4600	79·25	511·792	850·735	662·285	0·190	2·0889
12·0	462·207	+ 189·207	123·254	61·627	51·356	25·6780	79·25	510·746	851·912	663·462	0·175	2·1060

Col. 10 — 188·45

— 188·45

---

*) $\frac{2984}{1755}$

Tab XIX. b.

§ 97—100.

Pressure absolute Atmospheres. P.	Boiling Temperature.		To raise the Temperature of Steam, at const. Pressure. 8/30 T. Cal.	Latent Heat to overcome			Latent Heat of		Total Heat in 1 kg. of Steam of		Volume of 1 kg. of Steam. cbm. V.	V × P.
	Absolute T.	Deg. N. t.		Affinity of O. & H. 4/30 T. Cal.	External Pressure. 1/9 T. Cal.	Cohesion of Molecul. 1/18 T. Cal.	Liquefaction. 79·25 Calors.	Evaporation. 634—4/15 T. Calors.	Solid Water. Calors. 634+79·25+0·3 T.	Liquid Water. Calors. 634+0·3 T.—(72·8 +36·4+79·25) =(634+0·3 T.) —188·45.		
1	2	3	4	5	6	7	8	9	10	11	12	13
13·0	465·830 ° N	+ 192·830 ° N	124·222	62·111	51·759	25·8795	79·25	509·778	852·999	664·549	0·163	2·1242
14·0	469·194	+ 196·194	125·120	62·560	52·133	26·0665	79·25	508·880	854·008	665·558	0·153	2·1378
15·0	472·033	+ 199·033	125·876	62·938	52·448	26·2240	79·25	508·124	854·860	666·410	0·143	2·1510
16·0	475·278	+ 202·278	126·742	63·371	52·809	26·4045	79·25	507·258	855·833	667·383	0·135	2·1664
17·0	478·049	+ 205·049	127·480	63·740	53·117	26·5585	79·25	506·520	856·665	668·215	0·128	2·1794
18·0	480·666	+ 207·666	128·076	64·088	53·407	26·7035	79·25	505·924	857·450	669·000	0·122	2·1906
19·0	483·145	+ 210·145	128·840	64·420	53·683	26·8415	79·25	505·150	858·193	669·743	0·116	2·2021
20·0	485·500	+ 212·500	129·200	64·600	53·833	26·9165	79·25	504·800	858·900	Col. 10 — 188·46. 670·450	0·111	2·2120
25·0	497·004	+ 224·004	132·535	66·268	55·223	27·6115	79·25	501·465	862·351	673·901	0·0906	2·2650
30·0	506·500	+ 233·500	135·067	67·534	56·278	28·1390	79·25	498·933	865·200	676·750	0·0769	2·3070
35·0	514·966	+ 241·966	137·323	68·662	57·218	28·6090	79·25	496·677	867·740	679·290	0·0671	2·3474
40·0	522·250	+ 249·250	139·267	69·634	58·028	29·0140	79·25	494·733	869·925	681·475	0·0595	2·3804
45·0	528·897	+ 255·897	141·038	70·519	58·766	29·3830	79·25	492·962	871·919	683·469	0·0536	2·4106
50·0	534·850	+ 261·850	142·627	71·314	59·428	29·7140	79·25	491·373	873·705	685·255	0·0488	2·4380
55·0	540·337	+ 267·337	144·089	72·044	60·037	30·0185	79·25	489·911	875·351	686·901	0·0478	2·4629
60·0	545·350	+ 272·350	145·399	72·700	60·583	30·2915	79·25	488·601	876·855	688·405	0·0414	2·4858
65·0	550·021	+ 277·021	146·671	73·336	61·113	30·5565	79·25	487·329	878·256	689·806	0·0368	2·5071
70·0	554·350	+ 281·350	147·825	73·913	61·594	30·7970	79·25	486·175	879·555	691·105	0·0361	2·5269
75·0	558·418	+ 285·418	148·950	74·455	62·046	31·0230	79·25	485·050	880·775	692·325	0·0339	2·5455
80·0	562·225	+ 289·225	149·826	74·963	62·469	31·2345	79·25	484·174	881·917	693·467	0·0320	2·5624
85·0	565·829	+ 292·829	150·888	75·444	62·870	31·4350	79·25	483·207	882·999	694·549	0·0303	2·5789
90·0	569·225	+ 296·225	151·793	75·896	63·247	31·6235	79·25	482·207	884·017	695·567	0·0288	2·5947
95·0	572·460	+ 299·460	152·657	76·328	63·607	31·8035	79·25	481·343	884·988	696·538	0·0275	2·6096
100·0	575·500	+ 302·500	153·466	76·733	63·944	31·9720	79·25	480·534	885·900	697·450	0·0262	2·6230
200·0	622·775	+ 349·775	166·030	83·015	69·179	34·5895	79·25	467·970	900·082	711·632	0·0142	2·8380
300·0	654·275	+ 381·275	174·473	87·236	72·697	36·3485	79·25	459·527	909·532	721·082	0·00994	2·9820
400·0	677·900	+ 403·900	180·773	90·386	75·322	37·6610	79·25	453·227	916·620	728·170	0·00779	3·1160
500·0	696·800	+ 423·800	185·813	92·906	77·422	38·7110	79·25	448·187	922·290	733·840	0·00635	3·1750
1000·0	757·750	+ 484·750	202·066	101·033	84·194	42·0970	79·25	431·934	940·575	752·125	0·00345	3·4500
10000·0	1031·125	+ 758·125	274·961	137·480	114·567	57·3835	79·25	359·039	1022·587	834·137	0·000470	4·70002
1	2	3	4	5	6	7	8	9	10	11	12	13

Diagram G.

Pressure and Weight of saturated Steam

of 240° N abs to 470° N absolute.

Fig. 3.

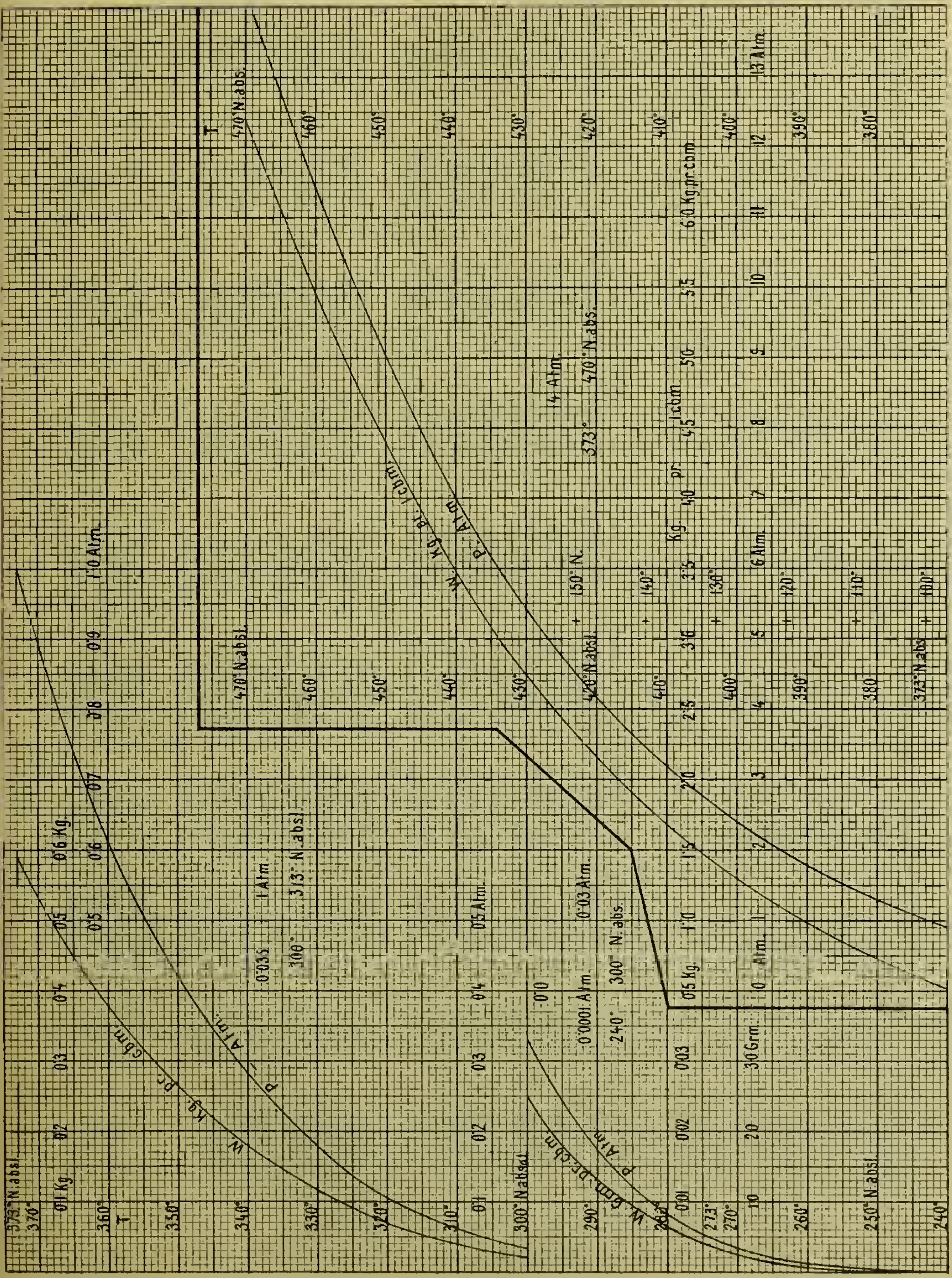


Fig. 2.

Fig. 1.

Fig. 1. Pressure of steam in atm. between 240° and 300° N abs. Weight of 1 cbm. in grammes.
» 2. » » » » » » 300° » 373° N abs. » » 1 » » kg.
» 3. » » » » » » 373° » 470° N abs. » » 1 » » »
Example: Pressure at 263° N abs. = 0·0016 atm. Weight pr. 1 cbm. = 1 gram.
» 290° N » = 0·010 » » » 1 » = 13 »
» 350° N » = 0·42 » » » 1 » = 0·26 kg.
» 451° N » = 9·25 » » » 1 » = 4·50 »

Tab. XX a.

§ 99.

Temperature, Pressure, Weight and Heat pro cbm. saturated Steam.

Pressure, absolute Atmospheres. P.	Boiling Temperature.		Weight pr. cbm. Steam. Kg. W.	To raise the Temperature of Steam at const. Pressure. Calors.	Latent Heat to overcome.			Latent Heat.		Total Heat in 1 cbm. Steam.	
	Absol. ⁰ N. T.	⁰ N t.			The Affinity of O & H. Calors.	The external Pressure. Calors.	The Cohesion of Molecules. Calors.	Heat of Liquefaction. Calors.	Heat of Evaporation. Calors.	From Ice. Calors.	From liquid Water. Calors.
1	2	3	4	5	6	7	8	9	10	11	12
0.000000	219·375	— 53·625	0·000000000								
0·000001	225·222	— 47·777	0·000000974	117/2000000	117/4000000	39/1600000	39/3200000	0·0000772	0·0006175	0·00076055	
0·00001	232·333	— 40·666	0·00000944	117/200000	117/400000	39/160000	39/320000	0·0007483	0·0059884	0·0073928	
0·0001	243·000	— 30·000	0·00009028	117/20000	117/40000	39/16000	39/32000	0·007154	0·057236	0·70972	
0·0002	247·147	— 25·853	0·00017752	117/10000	117/20000	39/8000	39/16000	0·01407	0·11255	0·13978	
0·0003	249·912	— 23·088	0·00026334	351/20000	351/40000	117/16000	117/32000	0·02087	0·16695	0·20753	
0·0004	251·996	— 21·004	0·00034822	117/5000	117/10000	39/4000	39/8000	0·02796	0·22077	0·27479	
0·0005	253.649	— 19·351	0·00043244	117/4000	117/8000	39/3200	39/6400	0·03426	0·27412	0·34129	
0·0006	255·027	— 17·973	0·00051612	351/10000	351/20000	117/8000	117/16000	0·04090	0·32722	0·40761	
0·0007	256·212	— 16·788	0·00059936	819/20000	819/40000	273/16000	273/32000	0·04761	0·38090	0·46459	
0·0008	257·250	— 15·750	0·00068260	117/2500	117/5000	39/2000	39/4000	0·05406	0·43252	0·53929	
0·0009	258·171	— 14·829	0·00076475	1053/20000	1053/40000	351/16000	351/32000	0·06061	0·48485	0·60470	
0·0010	259·000	— 14·000	0·0008474	117/2000	117/4000	39/1600	39/3200	0·0671	0·5370	0·66994	
0·0020	265·221	— 7·779	0·0016543	117/1000	117/2000	39/800	39/1600	0·1311	1·0488	1·31152	
0·0030	269·368	— 3·632	0·0024432	351/2000	351/4000	117/1600	117/3200	0·1930	1·5439	1·93433	
0·0040	272·494	— 0·506	0·0032203	117/500	117/1000	39/400	39/800	0·2552	2·0416	2·56010	
0·0042	273·000	± 0·000	0·0033750	2457/20000	2457/40000	819/8000	819/16000	0·2675	2·1398	2·68363	2·04658
0·005	274·973	+ 1·973	0·0039890	117/400	117/800	39/320	39/640	0·3161	2·5290	3·17423	2·42360
0·006	277·041	+ 4·041	0·0047511	351/1000	351/2000	117/800	117/1600	0·3767	3·0136	3·78521	2·88952
0·007	278·818	+ 5·818	0·0055076	819/2000	819/4000	273/1600	273/3200	0·4365	3·4918	4·38886	3·35108
0·008	280·374	+ 7·374	0·0062595	117/250	117/500	39/200	39/400	0·4961	3·9686	4·99110	3·81149
0·009	281·756	+ 8·756	0·0070074	1053/2000	1053/4000	351/1600	351/3200	0·5553	4·4427	5·59039	4·21981
1·01	283·000	+ 10·000	0·0077500	117/200	117/400	39/160	39/320	0·6240	4·9921	6·27426	4·80377
0·02	292·331	+ 19·331	0·0150087	117/100	117/200	39/80	39/160	1·1894	9·5155	12·02121	9·19282
0·03	298·552	+ 25·552	0·0220439	351 200	351 400	117/160	117/320	1·7418	13·9344	17·65054	13·50870
0·04	303·218	+ 30·218	0·0289396	117 50	117 100	39 40	39/80	2·2935	18·3476	23·27351	17·81988

1	2	3	4	5	6	7	8	9	10	11	12
0·05	306·960	+ 33·960	0·0357335	117/40	117/80	39/32	39/64	2·8318	22·6541	28·77649	22·04264
0·06	310·061	+ 37·061	0·0424513	351/100	351/200	117/80	117/160	3·3643	26·9146	34·22765	26·22757
0·07	312·727	+ 39·727	0·0491043	819/200	819/400	273/160	273/320	3·8915	31·1318	39·63020	30·37655
0·08	315·060	+ 42·060	0·0557367	117/25	117/50	39/20	39/40	4·4146	35·3164	44·99595	34·49851
0·09	317·134	+ 44·134	0·0622568	1053/200	1053/400	351/160	351/320	4·9328	39·4622	50·31812	38·58839
0·1	319·000	+ 46·000	0·06877	117/20	117/40	39/16	39/32	5·4501	43·6009	55·63221	42·67230
0·2	332·997	+ 59·997	0·131758	117/10	117/20	39/8	39/16	10·4416	83·5329	107·13706	82·30747
0·3	341·328	+ 68·328	0·192813	351/20	351/40	117/16	117/32	15·2815	122·2522	157·27750	120·93928
0·4	349·327	+ 76·327	0·251197	117/5	117/10	39/4	39/8	19·9070	159·2565	205·48853	158·15118
0·5	354·940	+ 81·940	0·309031	117/4	117/8	195/16	195/32	24·4901	195·9209	253·31726	185·08179
0·6	359·592	+ 86·592	0·366040	351/10	351/20	117/8	117/16	29·00005	232·0644	300·55997	231·58120
0·7	363·591	+ 90·591	0·422349	819/20	819/40	273/16	273/16	33·4671	267·7365	347·26423	267·68231
0·8	367·091	+ 93·091	0·478083	234/5	234/10	39/2	39/4	37·8824	303·0593	393·59168	303·51042
0·9	370·201	+ 97·201	0·533325	1053/20	1053/40	351/16	351/32	42·2667	338·3333	439·63125	339·12458
1·0	373·000	+ 100·000	0·588137	117/2	117/4	195/8	195/16	46·6098	372·8787	485·30102	374·46665
1·1	375·854	+ 102·854	0·641378	1287/20	1287/40	429/16	429/32	50·8992	407·1933	530·48623	409·45220
1·2	378·478	+ 105·478	0·69556	351/5	351/10	117/4	117/8	55·1120	440·8957	574·98266	443·93189
1·3	380·887	+ 107·887	0·74874	1521/20	1521/40	507/16	507/32	59·3633	474·9064	619·82591	478·66487
1·4	383·129	+ 110·129	0·80162	819/10	819/20	273/8	273/16	63·5525	508·4202	664·21023	512·98754
1·5	385·223	+ 112·223	0·85421	351/4	351/8	585/16	585/32	67·6772	541·4176	707·81354	546·88271
1·6	387·186	+ 114·186	0·90654	468/5	234/5	39	39/2	71·8495	574·7960	751·94551	581·09329
1·7	389·033	+ 116·033	0·95605	1989/20	1989/40	663/16	663/32	75·9827	607·8619	795·72593	615·04520
1·8	390·777	+ 117·777	1·01046	1053/10	1053/20	351/8	351/16	80·2125	641·7004	840·37546	649·63659
1·9	392·431	+ 119·431	1·06213	2223/20	2223/40	741/16	741/32	84·2189	673·7513	883·01399	682·74832
2·0	393·996	+ 120·996	1·11359	117	117/2	195/4	195/8	88·2517	706·0134	925·89003	716·03180
2·5	401·685	+ 128·685	1·36534	585/4	585/8	579/16	579/32	108·2650	866·1202	1138·91649	880·47114
3·0	407·993	+ 134·993	1·61308	351/2	351/4	485/8	485/16	127·8226	1022·5806	1347·84072	1043·84457
3·5	413·637	+ 140·637	1·85625	819/4	819/8	1365/16	1365/32	147·1134	1176·9074	1554·36454	1204·54091
4·0	418·491	+ 145·491	2·09682	234	117	195/2	195/4	166·1426	1329·1405	1758·53302	1363·45964
4·5	422·922	+ 149·922	2·33421	1053/4	1053/8	1455/16	1455/32	185·1635	1481·3084	1962·62821	1522·32447
5·0	426·889	+ 153·889	2·56946	585/2	585/4	975/8	975/16	203·6297	1629·0376	2161·72956	1677·51482
5·5	430·568	+ 157·568	2·80226	1287/4	1287/8	2145/16	2145/32	222·6124	1780·8989	2365·48000	1836·12606
6·0	433·888	+ 160·888	3·03362	351	351/2	485/4	485/8	240·4430	1923·5437	2558·86165	1987·10798
6·5	437·002	+ 164·002	3·26300	1521/4	1521/8	2535/16	2535/32	258·6488	2069·1906	2755·62067	2140·57499
7·0	439·886	+ 166·886	3·49096	819/2	819/4	1365/8	1365/16	276·7109	2213·6876	2951·08554	2293.08974
7·5	442·598	+ 169·598	3·71740	1755/4	1755/8	2925/16	2925/32	294·6097	2356·8773	3145·08073	2444·52313
8·0	445·135	+ 172·135	3·94262	468	234	195	195/2	312·5000	2500·0000	3339·00000	2595·90064
8·5	447·175	+ 174·175	4·16993	1989/4	1989/8	3315/16	3315/32	330·4837	2643·8699	3533·75988	2747·89666
9·0	449·801	+ 176·801	4·38944	1053/2	1053/4	1455/8	1455/16	347·8929	2783·1431	3723·34858	2896·09214
9·5	451·958	+ 178·958	4·61340	2223/4	2223/8	3705/16	3705/32	365·5443	2924·3542	3915·11727	3045·88295
10·0	454·000	+ 181·000	4.832043	585	585/2	975/4	975/8	382·9398	3063·5187	4104·5836	3193·4334
11·0	458·282	+ 185·282	5·26558	1287/2	1287/4	2145/8	2145/16	317·3249	3338·5993	4479·8617	3487·7082
12·0	462·207	+ 189·207	5·69550	702	351	585/2	585/4	451·5669	3612·5356	4853·8526	3780·0634

Tab. XX b.

§ 99.

Pressure, absolute Atmospheres. P.	Boiling Temperature.		Weight pr. cbm. Steam. Kg. W.	To raise the Temperature of Steam at const. Pressure. Calors.	Latent Heat to overcome.			Latent Heat.		Total Heat in 1 cbm. Steam.	
	Absol. ° N. T.	° N. t.			The Affinity of H & O. Calors.	The external Pressure Calors.	The Cohesion of Molecules. Calors.	Heat of Liquefaction. Calors.	Heat of Evaporation. Calors.	From Ice Calors.	From liquid Water. Calors.
1	2	3	4	5	6	7	8	9	10	11	12
13·0	465·830	+ 192·830	6·12214	1521/2	1521/4	2535/8	2535/16	485·0061	3880·0490	5210·6176	4067·3128
14·0	469·194	+ 196·194	6·54580	819	819/2	1365/4	1365/8	518·9096	4151.2770	5591·5616	4357·5243
15·0	472·033	+ 199·033	6·97096	1755/2	1755/4	2925/8	2925/16	522·6499	4421·1994	5961·0369	4646·8807
16·0	475·278	+ 202·278	7·38536	936	468	390	195	585·3951	4683·1610	6321·5561	4929·6620
17·0	478·049	+ 205·049	7·80124	1989/2	1989/4	3315/8	3315/16	618·1747	4945·3978	6682·3850	5212·4162
18·0	480·666	+ 207·666	8·21515	1053	1053/2	1755/8	1755/8	651·1915	5209·5316	7045·3481	5496·8682
19·0	483·145	+ 210·145	8·62707	2223/2	2223/4	3705/8	3705/16	683·7791	5470·2330	7404·4496	5778·5652
20·0	485·500	+ 212·500	9·037075	1170	585	975/2	975/4	716·2222	5729·7777	7762·2500	6059·1322
25·0	497·004	+ 224·004	11·03487	2925/2	2925/4	4875/8	4875/16	874·7242	6997·7925	9517·8291	7437·8070
30·0	506·500	+ 233·500	12·99358	1755	1755/2	2925/4	2925/8	1030·5592	8244·4733	11249·4075	8798·8223
35·0	514·966	+ 241·966	14·90996	4095/2	4095/4	6825/8	6825/16	1181·6009	9452·8075	12937·8459	10128·0953
40·0	522·250	+ 249·250	16·80230	2340	1170	975	975/2	1331·7090	10653·6717	14617·8806	11451·1859
45·0	528·897	+ 255·897	18·66502	5265/2	5265/4	8775/8	8775/16	1479·3728	11834·9823	16275·9175	12758·1091
50·0	534·850	+ 261·850	20·50809	2925	2925/2	4875/4	4875/8	1625·0513	13000·4102	17916·0864	14051·4966
55·0	540·337	+ 267·337	22·32981	6435/2	6435/4	10725/8	10725/16	1769·7633	14158·1063	19547·5571	15339·2052
60·0	545·350	+ 272·350	24·13587	3510	1755	2925/2	2925/4	1912·8651	15302·9206	21164·5357	16615·8994
65·0	550·021	+ 277·021	25·92515	7605/2	7605/4	12675/8	12675/16	2054·7057	16437·6458	22770·1641	17884·2424
70·0	554·350	+ 281·350	27·70136	4095	4095/2	6825/4	6825/8	2195·3517	17562·8135	24365·0402	19144·6740
75·0	558·418	+ 285·418	29·46417	8775/2	8775/4	14625/8	14625/16	2335·0030	18680·0236	25950·9640	20398·5185
80·0	562·225	+ 289·225	31·57099	4680	2340	1950	975	2474·2429	19793·5432	27533·1861	21649·6394
85·0	565·829	+ 292·829	32·95497	9945/2	9945/4	16575/8	16575/16	2612·0633	20896·5063	29102·6320	22891·3598
90·0	569·225	+ 296·225	34·68532	5265	5265/2	8775/4	8775/8	2748·4391	21987·5131	30659·0772	24122·9170
95·0	572·460	+ 299·460	36·40537	11115/2	11115/4	18525/8	18525/16	2884·9654	23079·7233	32216·8762	25356·6651
100·0	575·500	+ 302·500	38·11904	5850	2925	4875/2	4875/4	3021·3496	24170·7968	33773·3964	26588·8749
200·0	622·775	+ 349·775	70·45082	11700	5850	4875	4875/2	5584·9190	44679·3524	63426·7714	50146·2921
300·0	654·275	+ 381·275	100·58844	17550	8775	14625/2	14625/4	7972·8370	63782·6962	91499·2832	72439·9271
400·0	677·900	+ 404·900	129·44387	23400	11700	9750	4875	10173·2991	81386·3928	117884·6919	93693·4211
500·0	696·800	+ 423·800	157·41605	29250	14625	24375/2	24375/4	12480·3150	99842·5197	145229·0846	115551·9193
1000·0	757·750	+ 484·750	289·52550	58500	29250	24375	24375/2	22971·0145	183768·1159	272551·6304	217928·4420
10000·0	1031·125	+ 758·125	2127·65050	585000	292500	243750	121875	168606·9766	1348855·8123	2175587·7889	1774654·2375
1	2	3	4	5	6	7	8	9	10	11	12

Explanation of Diagram F and G.

Diagram F.

1. Vertical columne TT. 0° to 500° N absolute. Each line 5° N.
2. Horizontal line at 373° N abs. Boiling temperature, 1 atm. pressure.
3. » row 1 to 39 cbm. volume pr. 1 kg. steam (cbm.)
   » 1 to 39 divided by 5 gives weight (kg.) pr. 1 cbm. steam.
4. » row 480 to 740 cal. heat in 1 kg. steam.
5. » line at 273° N abs. (± 0° N) = 0·0042 atm. pressure of steam.
6. » row V × P. volume × pressure (cbm. × atm.)
7. » » 0 — 1 — 20 atm., pressure of steam.
8. Curve P. atm. Pressure (atm.), due to temperature T.
9. » W. Kg. pr. cbm. weight of one cbm. steam in kg.
10. » V. volume of one kg. steam in cbm.; from 300° to 500° N abs.
11. Diagonal, *latent calor pr. 1 kg.* Latent heat in 1 kg. steam.
12. » *Calor. pr. kg. sq. liqv.* The total heat of evaporation pr. 1 kg. liquid water from 273° N abs. to 500° N abs.
13. » *Total abs. Cal. pr. 1 kg.* Total heat (Calorier) in 1 kg. steam from 0° N abs. to 500° N absolut.
14. V × P. Product of volume (cbm. pr. 1 kg.) × pressure in atmospheres.

Examples. Given: Temperature T = 425° N abs. *Required:*

Pressure of steam. Where ordinate from 425° N intersects curve P. Atm. does abscissa, on row 7 show 4·75 atmospheres.

Volume. Cub. m. pr. 1 kg. steam. Where ordinate from 425° N abs. intersects curve V, does abscissa from point of intersection on horizontal row 1—39. show volume 0·4 cbm. pr. kg.

Weight, kg. pr. cbm. steam. Where ordinate from 425° N abs. intersects curve W. kg. pr. cbm. does abscissa from point of intersection, on horizontal row 1—39. show weight 12·5/5 = 2·5 kg. pr. cbm.

Calors, absolute in 1 kg. steam. Where ordinate from 425° N abs. intersects diagonale, Total absol. Cal. pr. 1 kg. does abscissa from point of intersection on horizontal row 820—860 show the required, 841 Cal. pr. 1 kg. steam.

Calors, required to convert 1 kg. liquid water of 273° N abs. into steam of 425° N abs. Where ordinate from 425° N abs. intersects diagonale, *calor pr. kg. aq. liqv.* does abscissa from point of intersection on horizontal row, *calor pr. 1 kg.* show the required, 652 cal. pr. 1 kg. steam.

Latent heat in 1 kg. steam. Where ordinate from 425° N abs. intersects diagonale, *Latent calor pr. 1 kg.* does abscissa from point of intersection on horizontal row *calor pr. 1 kg.* show the required 5·21 cal.

V × P. Where ordinate from 425° N abs. intersects diagonale V × P does abscissa from point of intersection, on horizontal row V × P, show the required product = 1·93. ($219^{3}/_{8}$° N abs. : 425° N abs. = 1 : 1·93).

Given: Pressure of steam 11·5 atmospheres. Required:

Temperature. Where abscissa from 11·5 atm. (from horizontal row 1—20 atm.) intersect curve P. Atm. does ordinate from point of intersection on vertical columne T, show temperature 460° N absolute. 460° N abs. — 273° N abs. = + 187° N.

Continued pag. 51.

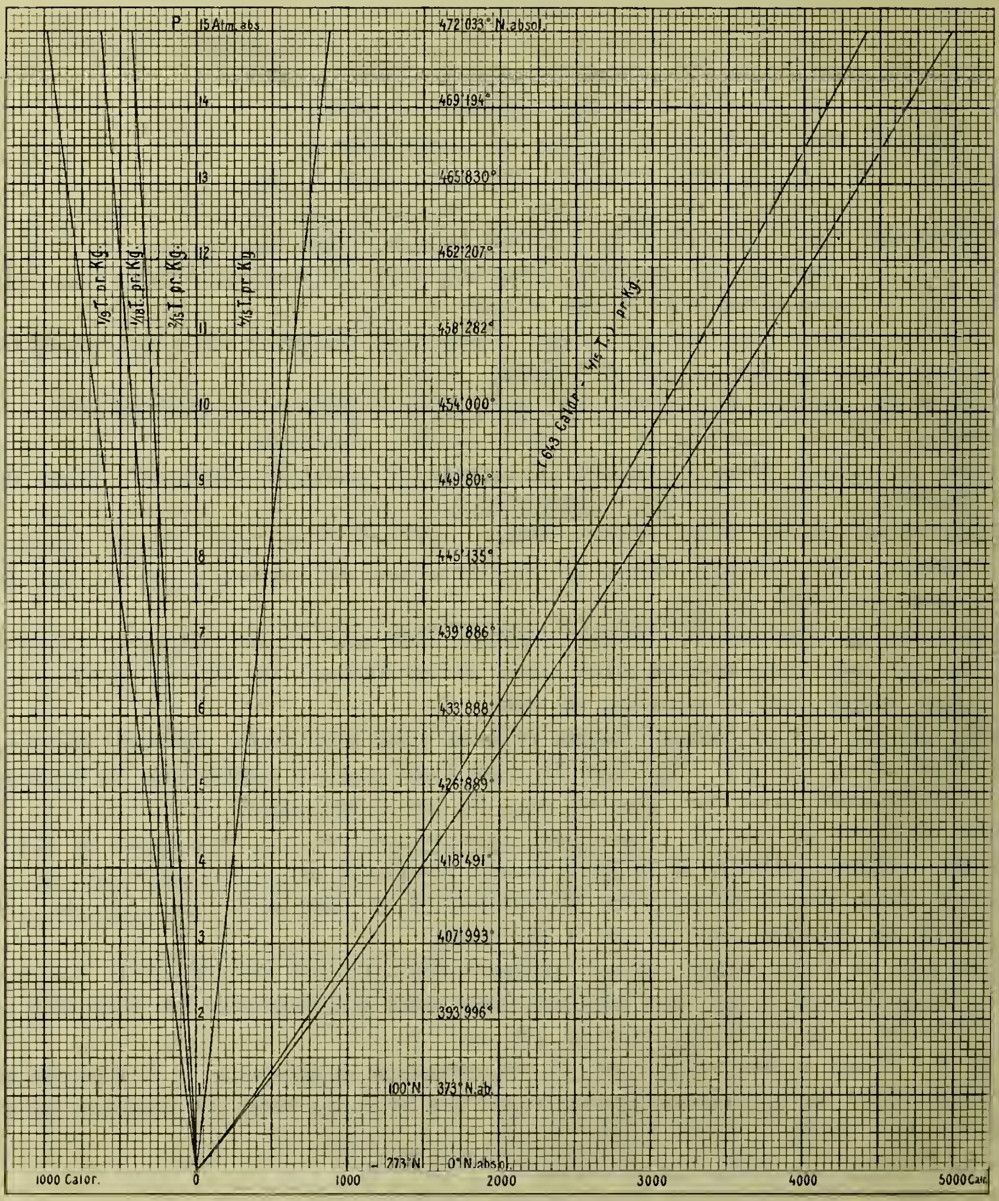
Diagram H.
§ 85—99.

Evaporation of Water.

Absolute Heat (Calors)
in 1 cbm. saturated Steam from 0 to 15 Atmospheres.

Heat of Evaporation.

Heat of
Liquefaction.



Volume pr. 1 kg. and all other values are found from the abs. temperature in the manner shown in the first example.

Diagram G shows the temperature from 240^0 to 470^0 N abs., the pressure and the weight pr. cbm. in larger scale and the values may consequently be read off more accurate than from diagram F.

§ 94. The temperatures, for pressures between 10 and 20 atmospheres, are found in similar way, as the former by means of Table XVIII.

The temperature T, is for 10 atm. = 454^0 N abs. and
T » » 20 » = 485·50^0 N abs.
and difference t = 31·50^0 N.

Tab. XVIII.

Pressure P.	*Volume V.*		*Ratio of increased Temperature.*		
11 Atm.	1/11	= 0·090909	0·0909		= 0·0909
12 »	1/12	= 0·0833	0·0909	+ 0·0833	= 0·1742
13 »	1/13	= 0·0769	0·1742	+ 0·0769	= 0·2511
14 »	1/14	= 0·0714	0·2511	+ 0·0715	= 0·3226
15 »	1/15	= 0·0666	0·3226	+ 0·0666	= 0·3892
16 »	1/16	= 0·0625	0·3892	+ 0·0625	= 0·4517
17 »	1/17	= 0·0588	0·4517	+ 0·0588	= 0·5106
18 »	1/18	= 0·0555	0·5106	+ 0·0555	= 0·5661
19 »	1/19	= 0·0526	0·5661	+ 0·0526	= 0·6187
20 »	1/20	= 0·0500	0·6187	+ 0·0500	= 0·6687
1.	2.	3.	4.	5.	6.

Example. Required the abs. temperature for 16 atmospheres.
0·6687 : 0·4517 = 31·50^0 N : 21·278^0 N rise of temperature
T = 454·000^0 N abs.
T = 475·278^0 N absolute.

§ 95. In similar way do we find the temperatures for 21 to 29, for 31 to 39 . . . 91 to 99 atmospheres, by means of the table.

At 10 times increase of pressure is the increase of temperature 2 : 3
» 100 times » » $= 2^2 : 3^2 = 4 : 9$
» 1000 times » » $= 2^3 : 3^3 = 8 : 27$

&c and from the temperature, due to any known pressure, the temperature for a pressure 10, 100, or 1000 times higher or lower may thus be found.

Example: Given absolute temperature for 12 atmospheres = 462,207^0 N abs.:
Required: temperature for 120 atmospheres.
T for 10 atmospheres = 454^0 N abs.
T for 12 » = 462·207^0 N abs.,

Difference t = 8·207^0 N for 12 atm., consequently
t for 120 atm. = 2 : 3 = 8·207^0 N : 12·3105^0 N rise of temperature
T for 100 atmospheres = 575·5250^0 N abs.

T for 120 » = 587·8355^0 N abs.

Required: temperature for 0·012 atmospheres.
T for 10 atmospheres = 454° N abs.
T for 12 » = 462·207° N abs.,
Difference t = 8·207° N for 12 atm.
P = 0·012 atm. = 1/1000 of 12 atm. and $3^3 : 2^3 = 27 : 8$, consequently
t for 0·012 atm. = 27 : 8 = 8·207° N : 2·432° N rise of temperature
T for 0·010 atmospheres = 283·000° N abs.
T for 0·012 » = 285·432° N abs.

§ 96. For all pressures given in Tab. XVII & XVIII, the temperatures are calculated in the manner shown. A comparaison of the calculated temperatures, with those determined by experiments of M. M. Regnault, Prony, Arago, Girard and Dulong, shows the trustworthiness of the authors method.

From the diagrams F, G & H, the pressures due to any temperature and the temperatures due to any pressure may be read off direct, without any calculation.

§ 97. By means of the relations between absolute temperature and pressure af steam determined in the precedent paragraphs, and by the equations 1 & 2 (in § 89) do we find the weights pr. cbm., and the volumes (cbm.) pr. kg. of steam, due to any temperature or pressure, and these as well as the product V × P (volume × pressure) are entered into Tables XIX a, b and XX a, b and in Diagrams F, G & H and the regularity of the curves and the perfectly straight P × V line, bear witness to the correctness of the calculations.

§ 98. From the preceding, we are further enabled, with greater exactness than by the best experiments, to ascertain the quantity of heat, contained in one kg. or in one cbm. of saturated steam.

To produce 1 kg. saturated steam of 273° absolute and 0·0042 atmospheres pressure, from ice of 0° N absolute, are according to § 70—75 required;
heat of liquefaction and evaporation 9 × 79·25 cal. = 713·25 calors
and 0·3 cal. × 273° N abs. = 81·90 » consequently
1 kg. steam of 273° N abs. from ice of 0° N abs., contains 795·15 cal. absol.
and as (§ 73) 1 kg. liquid water of 273° N abs. already contains 188·45 »
so absorb the *evaporation of 1 kg. water* of 273° N abs. 606·70 cal.

To produce *1 kg. saturated steam* of 373° N abs., and *1 atm.*, from *ice* of 0° N abs. are required: heat of liquefaction and evaporation 9 × 79·25 cal. = 713·25 cal.
0·3 cal. × 373° N abs. = 111·90 » consequently
1 kg. steam of 373° N abs. contains = 825·15 cal.
1 kg. liquid water of 273° N abs. contains = 188·45 » consequently
evaporation of 1 kg. liquid water of 273° N abs. absorbs = 636·70 cal.

To produce *1 kg. saturated steam* of *10 atm.* & 454° N abs. from *ice* of 0° N abs. are required: heat of liquefaction and evaporation 9 × 79·25 cal. = 713·25 cal.
0·3 cal. × 454° N abs. = 136·20 » consequently
1 kg. steam of 454° N abs. contains = 849·45 cal.
1 kg. liquid water of 273° N abs. contains 188·45 » consequently
evaporation of 1 kg. liquid water of 273° N abs. absorbs 661·00 cal.

§ 99. One calor heats 1 kg. liquid water 1^0 N., consequently does water of higher temperature than 273^0 N abs. (0^0 N) besides the 188·45 cal. contained in 1 kg. liquid water, contain 1 cal. for every 1^0 N temperature over freezing temperature; 1 kg. water of 10^0 N (283^0 N abs.) therefore contains 198·45 cal., and requires for evaporation 10 calors less than 1 kg. water of 273^0 N abs.

§ 100. The total heat in 1 kg. and in 1 cbm. steam from $219^3/_8{}^0$ N to 480^0 N absolute and its application as temperature and as physical, chemical and dynamic energy, calculated by author, is inserted in Tab. XIX & XX and drawn in Diagrams F. G. & H.

§ 101. From the preceding calculations, various useful formulæ may be deducted:

If T be the absolute boiling temperature of water, due to any pressure of steam.

t the absolute temperature $219^3/_8{}^0$ N $= 219·375 = \frac{1755}{8}$, where 1 cbm. H + $^1/_2$ cbm. O. (1 cbm. H_2O) of 1 atm. pressure = 1 kg. and 1 kg. = 1 cbm.

W the weight of 1 cbm. saturated steam, of absol. temperature T;
w the weight of 1 cbm. » » » » » t;
P the absolute pressure of » » » » » T;
p the absolute pressure of » » » » » t;
V the volume of 1 kg. saturated steam of temperature T;
v the volume (cbm.) of 1 kg. saturated steam of temperature t,

then is:

$$(1)\quad V \times W = 1.$$

$$(2)\quad V = \frac{8\ T}{1755\ P} = x \text{ cbm.}$$

$$(3)\quad W = \frac{1755\ P}{8\ T} = x \text{ kg.}$$

$$(4)\quad P = \frac{8\,W \times T}{1755} = x \text{ atmosphere.}$$

$$(5)\quad T = \frac{1755\ P \times V}{8} = x^0 \text{ N absolute temperature.}$$

$$(6)\quad P \times V = \frac{8\ T}{1755} =$$

$$(7)\quad V = \frac{1}{W} = x \text{ cbm.}$$

$$(8)\quad W = \frac{1}{V} = x \text{ kg.}$$

§ 102. The external caloric energy of steam, which counteracts the resistance of the atmosphere, or of steam in a boiler and which is able to perform dynamic or mechanical work, is:

pro 1 cbm. steam of 1 atmosphere pressure at any temperature = $24^3/_8$ cal.
» 1 kg. steam of any pressure it is = T^0 N abs. /9 »
» 1 kg. » » $219^3/_8{}^0$ N abs. it is = $219·375^0$ /9 = $24^3/_8$ »
» 1 kg. » » 273^0 N abs. » » = 273^0 /9 = $30^1/_3$ »
» 1 kg. » » 373^0 N abs. (1 Atm.) = 373^0 /9 = $41^4/_9$ »
» 1 kg. » » 454^0 N abs. (10 Atm.) = 454^0 /9 = $50^4/_9$ »

§ 103. The product of absolute pressure × volume (P × V) increases in direct proportion to the absolute temperature of steam.

Is P × V for 1 kg. steam of 243° N abs. = 1·10769, then is
P × V » 1 » » » 273° N » = 1·24444 »
P × V » 1 » » » 373° N » = 1·70028 »
P × V » 1 » » » 454° N » = 2·06951 &c as shown in diagram G & H.

§ 104. The weight of one cbm. steam (W) may also be found for any pressure and temperature by graphic construction, if the volume pro kg. (V) is known, and in similar way V may be found if W is known.

According to § 101 is $W \times V = 1$, consequently is

$$\log W + \log. V = \log. 1.$$

If we in a diagram, on the vertical ordinates plot the pressures of steam (in atmospheres) and on the abscisses, whose length, drawn to any scale, = 1000, the logarithms W + V = 1000, due to a convenient number of pressures, a curve uniting the points of jointure of log. W and log. V, will than indicate the weights and volumes due to all intermediate pressures in the diagram. The calculation can also be performed by means of the slide rule.

§ 105. From the composition of steam (§ 11—12) is evident, that saturated steam of any pressure and temperature must be exactly 9 times as heavy, as hydrogen, or 9/16 as heavy as oxygen, of equal pressure and temperature.

Combustion.

§ 106. If a substance is burnt, we feel the heat produced, and see flames and light emit from the burning object, and we have thus been led to imagine, that it is the visible object only, which burns, and the heat develloped in the process of burning, we commonly consider to be the quantity of heat, which the burning substance, for instance 1 kg. of coal is able to produce; — we might however just as well reverse the case, and consider the heat develloped in the process of combustion, as produced by combining a certain quantity of oxygen with the burning substance, and measure the heat produced by the quantity of oxygen, which combined with the burning substance.

§ 107. All substances combine with other substances in simple definite proportions, and this rule, no doubt also holds good in the chemical process termed combustion; we may therfore be sure, that *1 kg. of oxygen*, when combining with any other substance, *always will produce the same quantity of heat*, just as well as 1 kg. of carbon, if in combustion, or by any other chemical process combined with oxygen, always produces a certain and definite quantity of heat. If experimence in some cases seems to contradict this rule, and appearently gives different results, this can only be caused by imperfections in the method and apparatus used in the research, and such anomalies will by and by be found out and corrected.

§ 108. Of all substances at our disposal, capable of producing heat, carbon, hydrogen and oxygen, are the most generally applicable, and a correct determination of their and their compounds value, as producens of heat, will therefore be of the highest importance for science and industry, but as yet, the chief authorities disagree on this subject.

§ 109. The quantity of heat, produced by combustion of 1 kg. of hydrogen of 273^0 N abs., with 8 kg. of oxygen, of the same temperature, is found by

Tab. XXI.

Andrews = 33881 calors
Thomsen = 34181 »
Fischer = 34384 »
Favre & Silbermann = 34462 »
Berthelot = 34600 »
Humphrys = 34722 »
Dulong = 34742 »

The vapour of water produced, condenced to liquid water of $0^0 = 273^0$ N abs.

The heat produced by combustion of 1 kg. *carbon monoxide* is according to

Kennedy = 2389 calors
Favre & Silbermann = 2403 »
Fischer = 2440 »
Ferguson Bell = 2444 »
Dulong = 2489 »

As not two of these authors agree, it seems evident, that all are more or less erroneous.

§ 110. The calculation in § 80 shows, that 1 *kg. of hydrogen* of 0^0 N $= 273^0$ N abs. burnt with 8 kg. of oxygen of 273^0 N absolute, and the product of combustion cooled down to 273^0 N absolute, produces 34679·70 calors, which the author ventures in the following calculations, to round off to *34680 calors.* This figure, being the mean. of Messrs. Humphrys, Favre & Silbermann, Dulong, and Berthelots determinations, the author considers to be a correct standard, from which the heating power of other substances may be calculated, and consequently:

§ 111. As 1 kg. of hydrogen, of 273^0 N absolute, burnt with 8 kg. of oxygen, produces 34680 calors, it follows, that *1 cbm. hydrogen* of atmospheric pressure and 273^0 N absolute, weighing 5/56 1b, will produce $34680 \times 5/56 = 3096\,{}^3/_7$ cal. and further, that

§ 112. *1 kg. of oxygen* will produce $34680/8 = 4335$ calors and *1 cbm. oxygen* of atmospheric pressure and 273^0 N absolute, weighing 10/7 kg., will produce $4335 \times 10/7 = 6192\,{}^6/_7$ calors, and further,

§ 113. *1 kg. aeriform carbon* of 273^0 N absolute, burning with $1\,{}^1/_3$ kg. of oxygen, will produce $4335 \times 1\,{}^1/_3$ kg. $= 5780$ calors forming $2\,{}^2/_3$ kg. of carbon monoxide, and

§ 114. *1 cbm. aëriform carbon* of atmospheric density and 273^0 N absolute weighing 15/14 kg. will produce $15/14 \times 5780$ calors $= 6192\,{}^6/_7$ calors when burning with 1 cbm. oxygen of atmospheris pressure and 273^0 N absolute, forming *2 cbm. carbon monoxide* of 273^0 absolute.

§ 115. *1 kg. of ariform carbon* of 273^0 N absolute, burning with $2^2/_3$ kg. of oxygen, will produce 4335 × $2^2/_3$ kg. = 11560 calors, forming $3^2/_3$ kg. of *carbon dioxide*, and *1 cbm. aeriform carbon* of atmospheric density and 273^0 N absolute burning with 2 cbm. oxygen, of atmospheric density and 273^0 N absolute, will produce 2 × $6192^6/_7$ cal. = $12385^5/_7$ cal., and *form 2 cbm.* CO_2.

§ 116. *Carbon monoxide*; 1 kg. which contains $^3/_7$ kg. of aeriform carbon, burning with $^4/_7$ kg. of oxygen, will produce $^4/_7$ × 4335 calors = $2477^1/_7$ calors, forming $1^4/_7$ *kg. of carbon monoxide*; and 1 *cbm. of carbon monoxide* of atm. density and 273^0 N abs., containing $^1/_2$ cbm. of aeriform carbon, burning with $^1/_2$ cbm. oxygen, will produce $^1/_2$ × $6192^6/_7$ calors = $3096^3/_7$ calors, forming *1 cbm. of carbon dioxide.*

§ 117. *Combustion of solid carbon.* The heat produced by burning *pure solid carbon*, with $1^1/_3$ its weight of oxygen, to carbon monoxide, and with $2^2/_3$ its weight of oxygen to carbon dioxide, is given differently by various authorities, but the mean of their results is = 5/7 of the heat, produced by burning aeriform carbon and this leads to the following simple relation:

1 kg. of aeriform carbon, burnt to CO_2 produces sensible heat = 11560 cal.

1 kg. of solid carbon, burnt to CO_2 produces likewise = 11560 cal.
but in *gasifying the solid carbon*, 2/7 × 11560 cal. become latent = $3302^6/_7$ »
and only 2/7 × 11560 cal. = $8257^1/_7$ cal.
are set free as sensible heat.

§ 118. 1 kg. of *solid carbon*, burnt to CO produces $^1/_2$ × 11560 = 5780 cal.
in gasifying become latent = $3302^6/_7$ »
and the sensible heat produced is = $2477^1/_7$ cal.

§ 119. *Combustion of Hydrocarbons.* If we burn hydrocarbon gases with oxygen or air, the case is different, because the compound must be decomposed, before its components can unite with the oxygen, to form the new compounds, CO_2 and H_2O. As shown in §§ 109—115.

1 kg. hydrogen, burnt with 8 kg. oxygen, produces	34680	cal.
1 cbm. hydrogen of 1 atm. & 273^0 N abs., burnt with $^1/_2$ cbm. O produces	$3096^3/_7$	»
1 kg. *oxygen* combined with any substance, produses	4335	»
1 cbm. *oxygen* of 1 atm. & 273^0 N abs. = 10/7 kg.	$6192^6/_7$	»
1 kg. *aeriform carbon* burnt with $2^2/_3$ kg. O (to CO_2) produces	11560	»
1 cbm. *aeriform* 1 atm. & 273^0 N abs. burnt with 2 cbm. O (to CO_2)	$12385^5/_7$	»

§ 120. *Decomposing a hydrocarbon gas,* or separating the hydrogen contained in it from the carbon, *by the combined action of heat and the chemical affinity of oxygen*, will absorb *half* as much heat, as produced by the combustion of an equal quantity of hydrogen, or, for

1 kg. hydrogen 34680/2 = 17340 cal., and
1 cbm. » of 273^0 N. abs. & 1 atm. $3096^3/_7/2$ = $1548^3/_{14}$ »

§ 121. We find thus, if the products of combustion are cooled to 0^0 N (273^0 N abs.) the production of sensible heat by combustion of

Methane. 1 kg. methane burnt with 4 kg. O produces

4335 cal. × 4 kg. = 17340 cal.
separation of 1/4 kg. H requires 17340/4 = 4335 »
1 kg. methane produces sensible heat = 13005 cal. = 3 kg. O.

1 cbm. methane, of 273^0 N abs. and atmospheric pressure, burnt with 2 cbm. O produces,

$6192^6/_7$ cal. × 2 cbm. = $12385^5/_7$ cal.
separation of 2 cbm. H, absorbs $1548^3/_{14}$ cal. × 2 = $3096^3/_7$ »
1 cbm. methane produces sensible heat = $9289^2/_7$ cal. = $1^1/_2$ cbm. O.

§ 122. *Acetylene. 1 kg. acetylene* burnt with 40/13 kg. O produces

4335 cal. × 40/13 kg. = $13338^6/_{13}$ cal.
separation of 1/13 kg. H absorbs 17340/13 = $1333^{11}/_{13}$ »
1 kg. acetylene produces sensible heat = $12004^8/_{13}$ cal. = 36/13 kg. O.

1 cbm. acetylene, of 273^0 N abs. and atmospheric pressure, burnt with $2^1/_2$ cbm. O produces

$6192^6/_7$ cal. × $2^1/_2$ cbm. = $15482^1/_7$ cal.
separation of 1 cbm. H, absorbs $1548^3/_{14}$ cal. × 1 cbm. = $1548^3/_{14}$ »
1 cbm. acetylene produces sensible heat = $13933^{13}/_{14}$ cal. = $2^1/_4$ cbm. O.

§ 123. *Ethylene. 1 kg. ethylene* burnt with 24/7 kg. O. produces,

4335 cal. × 24/7 kg. = $14862^6/_7$ cal.
separation of 1/7 kg. H, absorbs 17340/7 = $2477^1/_7$ »
1 kg. ethylene produces sensible heat = $12385^5/_7$ cal. = 20/7 kg. O.

1 cbm ethylene of 273^0 N abs. and atmospheric pressure with 3 cbm. O produces

$6192^6/_7$ cal. × 3 cbm. = $18578^4/_7$ cal.
separation of 2 cbm. H, absorbs $1548^3/_{14}$ cal. × 2 cbm. = $3096^3/_7$ »
1 cbm. ethylene produces sensible heat = $15482^1/_7$ cal. = $2^1/_2$ cbm. O.

§ 124. *Ethane. 1 kg. ethane* burnt with 56/15 kg. O produces

4335 cal. × 56/15 kg. = 16184 cal.
separation of 1/5 kg. H, absorb 17340/5 = 3468 »
1 kg. ethane produces sensible heat = 12716 cal. = 44/15 kg. O.

1 cbm. ethane of 273^0 N abs. and atm. pressure burnt with $3^1/_2$ cbm. O produces

$6192^6/_7$ cal. × $3^1/_2$ cbm. = 21675 cal.
separation of 3 cbm. H, absorbs $1548^3/_{14}$ cal. × 3 cbm. = $4644^9/_{14}$ »
1 cbm. ethane produces sensible heat = $17030^5/_{14}$ cal. = $2^3/_4$ cbm. O.

§ 125. *Allylene. 1 kg. allylene*, burnt with 16/5 kg. O produces

4335 cal. × 16/5 kg. = 13872 cal.
separation of 1/10 kg. H, absorbs 17340/10 cal. = 1734 »
1 kg. allylene produces sensible heat = 12138 cal. = 14/5 kg. O.

Tab. XXII.

The Products of Combustion, formed by Combustion of Gases with Oxygen.

All Gasvolumes are reduced to normal atmospheric pressure and 273^0 N abs.

Substance. 1 cbm.	Contains in 1 cbm. cbm.	Requires O. cbm.		Produces: cbm.	Contains in 1 kg. kg.	Requires O. kg.		Produces. kg.
Hydrogen	1 H +	$^1/_2$	=	1 H_2O	1 H +	8	=	9 H_2O
Carbon	1 C +	1	=	2 CO	1 C +	4/3	=	7/3 CO
»	1 C +	2	=	2 CO_2	1 C +	8/3	=	11/3 CO_2
Carbon monoxide	$^1/_2$ C + $^1/_2$ O +	$^1/_2$	=	1 CO_2	3/7C + $^4/_7$O +	4/7	=	11/7 CO_2
Methane	$^1/_2$ C + 2 H +	1 1	> 2	1 CO_2 2 H_2O	3/4 C + 1/4 H +	2 2	> 4	11/4 CO_2 9/4 H_2O
Acetylene	1 C + 1 H +	2 $^1/_2$	> $2^1/_2$	2 CO_2 1 H_2O	12/13 C + 1/13 H +	32/13 8/13	> 40/13	44/13 CO_2 9/13 H_2O
Ethylene	1 C + 2 H +	2 1	> 3	2 CO_2 2 H_2O	6/7 C + 1/7 H +	16/7 8/7	> 24/7	22/7 CO_2 9/7 H_2O
Ethane	1 C + 3 H +	2 $1^1/_2$	> $3^1/_2$	2 CO_2 3 H_2O	12/15 C + 3/15 H +	32/15 24/15	> 56/15	44/15 CO_2 27/15 H_2O
Allylene	$1^1/_2$ C + 2 H +	3 1	> 4	3 CO_2 2 H_2O	9/10 C + 1/10 H +	24/10 8/10	> 32/10	33/10 CO_2 9/10 H_2O
Propylene	$1^1/_2$ C + 3 H +	3 $1^1/_2$	> $4^1/_2$	3 CO_2 3 H_2O	6/7 C + 1/7 H +	16/7 8/7	> 24/7	22/7 CO_2 9/7 H_2O
Propane	$1^1/_2$ C + 4 H +	3 2	> 5	3 CO_2 4 H_2O	9/11 C + 2/11 H +	24/11 16/11	> 40/11	33/11 CO_2 18/11 H_2O
Butylene	2 C + 4 H +	4 2	> 6	4 CO_2 4 H_2O	6/7 C + 1/7 H +	16/7 8/7	> 24/7	22/7 CO_2 9/7 H_2O
Butane	2 C + 5 H +	4 $2^1/_2$	> $6^1/_2$	4 CO_2 5 H_2O	24/29 C + 5/29 H +	64/29 40/29	> 104/29	88/29 CO_2 45/29 H_2O
Pentane	$2^1/_2$ C + 6 H +	5 3	> 8	5 CO_2 6 H_2O	15/18 C + 3/18 H +	40/18 24/18	> 64/18	55/18 CO_2 27/18 H_2O
Benzene	3 C + 3 H +	6 $1^1/_2$	> $7^1/_2$	6 CO_2 3 H_2O	12/13 C + 1/13 H +	32/13 8/13	> 40/13	44/13 CO_2 9/13 H_2O
Dipropyl	3 C + 7 H +	6 $3^1/_2$	> $9^1/_2$	6 CO_2 7 H_2O	36/43 C + 7/43 H +	96/43 56/43	> 152/43	132/43 CO_2 63/43 H_2O
1	2	3	4	5	6	7	8	9

If the Gas is burnt with dry *atmospheric air instead of oxygen* than 4·7841 cbm. air for each 1 cbm. oxygen, or 4·3337 kg. air for each kg. oxygen are required, and to the products combustion must be added:

pr. cbm. oxygen 3·7841 cbm. N. A. und CO_2
pr. kg. » 3·3337 kg. » » » (§ 23.)

1 cbm allylene of 273^0 N abs. and atmospheric pressure burnt with 4 cbm. O produces,
$6192^6/_7$ cal. × 4 cbm. = $24771^3/_7$ cal.
separation of 2 cbm. H, absorbs $1548^3/_{14}$ cal. × 2 cbm. = $3096^3/_7$ »
1 cbm. allylene produces sensible heat = 21675 cal. = $3^1/_2$ cbm. O.

§ 126. *Propylene. 1 kg. propylene*, burnt with 24/7 kg. O produces 4335 cal. × 24/7 kg. = $14862^6/_7$ cal.
separation of 1/7 kg. H, absorbs 17340/7 cal. = $2477^1/_7$ »
1 kg. propylene produces sensible heat = $12385^5/_7$ cal. = 20/7 kg. O.

1 cbm. propylene of 273^0 N abs. and atmospheric pressure burnt with $4^1/_2$ cbm. O produces
$6192^6/_7$ cal. × $4^1/_2$ cbm. = $27867^6/_7$ cal.
separation of 3 cbm. H, absorbs $1548^3/_{14}$ cal. × 3 cbm. = $4644^9/_{14}$ »
1 cbm. propylene produces sensible heat = $23223^3/_{14}$ cal. = $3^3/_4$ cbm. O.

§ 127. *Propane. 1 kg. propane* burnt with 40/11 kg. O produces 4335 cal. × 40/11 kg. = $15763^7/_{11}$ cal.
separation of 2/11 kg. H, absorbs 17340 × 2/11 cal. = $3152^8/_{11}$ »
1 kg. propane produces sensible heat = $12610^{10}/_{11}$ cal. = 32/11 kg. O.

1 cbm. propane of 273^0 N abs. and atmospheric pressure, burnt with 5 cbm. O. produces
$6192^6/_7$ cal. × 5 cbm. = $30964^2/_7$ cal.
separation of 4 cbm. H, absorbs $1548^3/_{14}$ cal. × 4 cbm. = $6192^6/_7$ »
1 cbm. propane produces sensible heat = $24771^3/_7$ cal. = 4 cbm. O.

§ 128. *Butylene.* 1 *kg. butylene* burnt with 24/7 kg. O produces 4335 cal. × 24/7 kg. = $14862^6/_7$ cal.
separation of 1/7 kg. H, absorbs 17340/7 cal. = $2477^1/_7$ »
1 kg. butylene produces sensible heat = $12385^5/_7$ cal. = 20/7 kg. O.

1 cbm. butylene of 273^0 N abs. and atmospheric pressure burnt with 6 cbm. O produces
$6192^6/_7$ cal. × 6 cbm. = $37157^1/_7$ cal.
separation of 4 cbm. H, absorbs $1548^3/_{14}$ cal. × 4 cbm. = $6192^6/_7$ »
1 cbm. butylene produces sensible heat = $30964^2/_7$ cal. = 5 cbm. O.

§ 129. *Butane. 1 kg. butane* burnt with 104/29 kg. O produces 4335 Cal. × 104/29 kg. = $15546^6/_{29}$ cal.
separation of 5/29 kg. H, absorbs 17340 × 5/29 cal. = $2989^{19}/_{29}$ »
1 kg. butane produces sensible heat = $12556^{16}/_{29}$ cal. = 84/29 kg. O.

1 cbm. butane of 273^0 N abs. and atmospheric pressure, burnt with $6^1/_2$ cbm. O produces
$6192^6/_7$ cal. × $6^1/_2$ cbm. = $40253^4/_7$ cal.
separation of 5 cbm. H, absorbs 5 × $1548^3/_{14}$ cal. = $7741^1/_{14}$ »
1 cbm. butane produces sensible heat = $32512^1/_2$ cal. = $5^1/_4$ cbm. O.

§ 130. *Pentane.* 1 kg. pentane, burnt with 32/9 kg. O produces 4335 cal. × 32/9 kg. = $15413^1/_3$ cal.
separation of 1/6 kg. H, absorbs 17340 × 1/6 Cal. = 2890 »
1 kg. Pentane produced sensible heat = $12523^1/_3$ cal. = 26/9 kg. O.

1 cbm. pentane of 273^0 N abs. and atmospheric pressure, with 8 cbm. O produce
$6192^6/_7$ Cal. × 8 cbm. = $49542^6/_7$ cal.
separation of 6 cbm. H, absorb 6 × $1548^3/_{14}$ cal. = $9289^2/_7$ »
1 cbm. pentane produces sensible heat = $40253^4/_7$ cal. = $6^1/_4$ cbm. O.

§ 131. *Benzene Gas.* 1 kg. benzene burnt with 40/13 kg. O produces 4335 cal. × 40/13 kg. = $13338^6/_{13}$ cal.
separation of 1/13 kg. H, absorbs 17340 × 1/13 kg. = $1333^{11}/_{13}$ »
1 kg. benzene produces sensible heat = $12004^8/_{13}$ cal. = 36/13 kg. O.

1 cbm. benzene of 273^0 N abs. and atmospheric pressure with $7^1/_2$ cbm. O produces
$6192^6/_7$ cal. × $7^1/_2$ cbm. = $46446^3/_7$ cal.
separation of 3 cbm. H, absorbs 3 × $1548^3/_{14}$ cal. = $4644^9/_{14}$ »
1 cbm. benzene produces sensible heat = $41801^{11}/_{14}$ cal. = $6^3/_4$ cbm. O.

§ 132. *Dipropyl Gas.* 1 kg. dipropyl burnt with 152/45 kg. O produces 4335 cal. × 152/43 kg. = $15323^{31}/_{43}$ cal.
separation of 7/43 kg. H, absorbs 17340 × 7/43 kg. = $2822^{34}/_{43}$ »
1 kg. dipropyl produces sensible heat = $12500^{40}/_{43}$ cal. = 124/43 kg. O.

1 cbm. dipropyl of 273^0 N abs. and atmospheric pressure burnt with $9^1/_2$ cbm. O produces
$6192^6/_7$ cal. × $9^1/_2$ cbm. = $58832^1/_7$ cal.
separation of 7 cbm. H, absorbs $1548^3/_{14}$ cal. × 7 cbm. = $10837^1/_2$ »
1 cbm. dipropyl produces sensible heat = $47994^9/_{14}$ cal. = $7^3/_4$ cbm. O.

Tab. XXIII.

Sensible Heat produced by Combustion of Gases

of normal atmospheric pressure and 273⁰ N abs. and the products of combustion cooled down to 273⁰ N abs.

Substance.	Calculated by C. J. T. Hanssen (§ 109—137)					Experiments by:								
	1 kilogramme produces Calors.	Ratio O = 1.	Ratio between 1 kg : 1 cbm.	1 cbm. 1 Atm. 273^0 N abs. Calors.	Ratio O = 1.	Andrews.	Kennedy.	Humphrys.	Favre & Silbermann.	Dulong.	Thomsen.	Fischer.	F. Bell.	Letheby.
Oxygen	4335	1	7 : 10	$6192^{6}/_{7}$	1	4235		4340	4308	4343	4273	4298		
Hydrogen	34680	8	56 : 5	$3096^{3}/_{7}$	1/2	33881		34722	34462	34742	34181	34384	34166	34693
Carbon (aeriform) to CO	5780	4/3	14 : 15	$6192^{6}/_{7}$	1									
» » » CO_2	11560	8/3	14 : 15	$12385^{5}/_{7}$	2				11214					11544
Carbon monoxide » CO_2	$2477^{1}/_{7}$	4/7	4 : 5	$3096^{3}/_{7}$	1/2		2389		2403	2489		2440	2444	2403
Methane	13005	3	7 : 5	$9289^{2}/_{7}$	3/2		12889		13063			13300	13344	13063
Acetylene	$12004^{8}/_{13}$	36/13	56 : 65	$13933^{13}/_{14}$	9/4			11945						
Ethylene	$12385^{5}/_{7}$	20/7	4 : 5	$15482^{1}/_{7}$	5/2		11858	11942				12000	11944	11856
Ethane	12716	44/15	56 : 75	$17030^{5}/_{14}$	11/4			12444						
Allylene	12138	14/5	14 : 25	21675	7/2			11791						
Propylene	$12385^{5}/_{7}$	20/7	8 : 15	$23223^{3}/_{14}$	15/4							12000	11777	
Propane	$12610^{10}/_{11}$	32/11	28 : 55	$24771^{3}/_{7}$	4			12125						
Butylene	$12385^{5}/_{7}$	20/7	2 : 5	$30964^{2}/_{7}$	5									
Butane	$12556^{16}/_{29}$	84/29	56 : 145	$32512^{1}/_{2}$	21/4									
Pentane	$12523^{1}/_{3}$	26/9	14 : 45	$40253^{4}/_{7}$	13/2									
Benzene	$12004^{8}/_{13}$	36/13	56 : 195	$41801^{11}/_{14}$	27/4							(liquid)	10333	
Dipropyl	$12500^{40}/_{43}$	24/43	56 : 215	$47994^{9}/_{14}$	31/4									
Coal gas (17 candles)	12105·125	2·792	1 : 0·5233	6333·146	1·022									
Dowson gas	$1409^{65}/_{111}$	0·325	1 : 1·0534	$1486^{2}/_{7}$	0·171									
Generator gas	1309·616	0·302	1 : 0 5275	$1083^{3}/_{4}$	0·175									
Watergas	4335	1·0	7 : 5	$3096^{3}/_{7}$	1/2									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Oxygen 1/1000 kg. = 1 gramme produces $4^{67}/_{200}$ cal. = 4·3350 calors.

» 1 litre of normal atmospheric pressure

» and 273⁰ N abs. (0⁰ N) produces $6^{27}/_{140}$ cal. = 6·192857 calors.

§ 133. *Combustion of Gas-Compounds.* *Coal gas* (17 candles). 1 cbm. of 273^0 N abs. and atmospheric pressure.

contains litres;		*requires oxygen,*	*but produces only sensible heat like*	
methane	370·0	× 2 = 740·00 litres	370 × 3/2 = 555·00 litres	O
ethylene	25·0	× 3 = 75·00 »	25 × 5/2 = 62·50 »	»
propylene	12·0	× 9/2 = 54·00 »	12 × 15/4 = 45·00 »	»
benzene	13·0	× 15/2 = 97·50 »	13·0 × 27/4 = 87·75 »	»
carbon monoxide	52·5	× 1/2 = 26·25 »	52·5 × 1/2 = 26·25 »	»
hydrogen	490·0	× 1/2 = 245·00 »	490·0 × 1/2 = 245·00 »	»
		1237·75 litres		
carbon dioxide	4·0			
nitrogen	32·5			
oxygen	1·0	= 1·00 »	1·0 × 1 = 1·00 »	»
1 cbm. =	1000·0 litres	1236·75 litres O,	produces sensible heat, like 1022·50 litres	O

and as according to § 112, 1 litre O, produces $6^{27}/_{140}$ = 867/140 cal. sensible heat, the sensible heat, for 1 cbm. of the gas

= 1022·5 litre O × 867/140 cal. = 6332·196 calors.

As 1 cbm. of this gas of 273^0 N abs. and atmospheric pressure weighs = 5853/11200 kg. and 1 kg. 11200/5853 cbm. it follows, that 1 kg. for combustion requires

2·3666 cbm. = 3·3808 kg. oxygen and produces

6332·196 Cal. × 11200/5853 = 12116·966 calors of sensible heat.

§ 134. *Dowson Gas.* *1 cbm.* of 273^0 N abs. and atmospheric pressure

contains litres		*requires oxygen*	*produces sensible heat*	
hydrogen	260	× 1/2 = 130 litres	260 × 1/2 = 130 litres.	O
carbon monoxide	220	× 1/2 = 110 »	220 × 1/2 = 110 »	»
carbon dioxide	60			
nitrogen	460			
Oxygen		= 240 litres sensible heat	= 240 litres	O

consequently = 240 litres O × 867/140 cal. = $1486^2/_7$ calors.

1 kg. Dowson gas = 112/111 cbm. requires for combustion:

240 litres × 112/111 cbm. = $242^6/_{37}$ litres O = 64/185 kg. oxygen,

and produces 64/185 kg. × 4335 cal. = $1499^{25}/_{37}$ calors,

112/111 cbm. × $1486^2/_7$ » = $1499^{25}/_{37}$ » sensible heat.

§ 135. *Generator Gas.* *1 cbm.* of 273^0 N abs. and atmospheric pressure.

contains litres		*requires oxygen*	*produces sensible heat*	
hydrogen	56	× 1/2 = 28 litres	56 × 1/2 = 28 litres	O
methane	19	× 2 = 38 »	19 × 3/2 = 28·5 »	»
carbon monoxide	237	× 1/2 = 118·5 »	237 × 1/2 = 118·5 »	»
carbon dioxide	53			
nitrogen	635			
1 cbm. = litres	1000	requires 184·5 lit. O,	prod. sensib. heat = 175·0 litres	O

= 175 litres O × 867/140 cal. = $1083^3/_4$ calors, and

1 kg. generator gas = 2693/2240 cbm. requires 221·812 litres O

= 0·3169 kg. O, and produces $1083^3/_4$ cal. × 2693/2240 cbm. = 1309·616 cal. sensible heat.

§ 136. *Watergas*, H + CO. This mixture, which consists of equal volumes of hydrogen and carbon monoxide, is formed by passing steam (H_2O) through glowing carbon; the hydrogen is set free, and the oxygen combines with carbon, forming carbon monoxide.

1 kg. of steam of 373° N abs. (100° normal) and atmospheric pressure, consists of 1/9 kg. H and 8/9 kg. O, and forms, passing through glowing carbon and the product cooled to 273° N abs. (0° normal) at atmospheric pressure:

hydrogen 1/9 kg. = 56/45 cbm. H.
oxygen 8/9 kg. combines with 6/9 kg. carbon, forming 14/9 kg. = 56/45 » CO
1 kg. steam (of 273° N abs. & 1 atm. = 56/45 cbm.)
produces Watergas = 15/9 kg. = 112/45 cbm.

15/9 = 5/3 kg. watergas = 112/45 cbm. of 273° N abs. and atmospheric pressure, consequently
1 kg. = 112/75 cbm. of 273° N abs. & 1 atm. and 1 cbm. = 75/112 kg.
1 kg. Watergas contains 1/15 kg. H + 14/15 kg. CO = 56/75 cbm. H + 56/75 cbm. CO
1 cbm » » 1/2 cbm. H + 1/2 cbm. CO = 5/112 kg. H + 5/8 kg. CO.

§ 137. *The decomposition of 1 kg water*, by the united action of heat and the chemical affinity of carbon requires, as shown in § 117 & 120, evaporation of 1 kg. 0° N (273° N abs.) and separation of 1/9 kg. H from C.

1/9 kg. × 17340 cal. = $1926\,{}^{2}/_{3}$ cal. latent
gasifying of 2/3 kg. C absorbs
2/3 × $3302\,{}^{6}/_{7}$ cal. = $2201\,{}^{19}/_{21}$ » » $4127\,{}^{1}/_{7}$ cal.
2/3 kg. C burnt with 8/9 kg. O to CO
produce 8/9 × 4335 cal. = $3853\,{}^{1}/_{3}$ »
therfore heat absorbed pr. 1 kg. water, for 5/3 kg. watergas = $275\,{}^{5}/_{21}$ cal.
» » 3/5 » » 1 » » = $165\,{}^{1}/_{7}$ cal.
» » 1 cbm. watergas of 273° N abs. & 1 atm. = $110\,{}^{115}/_{196}$ »

§ 138. *Watergas burnt with oxygen*, requires
for 1/15 kg. H × 8 = 8/15 kg. O; for 1/2 cbm. H × 1/2 = 1/4 cbm. O
» 14/15 » CO × 1/2 = 7/15 » » » 1/2 » CO × 1/2 = 1/4 » »
for 1 kg. watergas 1 kg. O; for 1 cbm. watergas = 1/2 cbm. O

1 kg. watergas, burnt with 1 kg. O produces 1 × 4335 cal. = 4335 cal.
1 cbm. » of 273° N abs. & 1 atm., with 1/2 cbm. O 1/2 × $6192\,{}^{6}/_{7}$ cal. = $3096\,{}^{3}/_{7}$ »
and the *product af combustion af watergas* are:

pr. 1 kg. 1/15 kg. H + 8/15 kg. O = 9/15 kg. = 3/5 kg. steam (H_2O)
14/15 » CO + 7/15 » O = 21/15 » = 7/5 » CO_2
consequently products of combustion 30/15 kg. = 10/5 kg. = 2 kg.
pr. 1 cbm. 1/2 cbm. H + 1/4 cbm. O with 3 : 2 contraction = 1/2 cbm. H_2O
1/2 » CO + 1/4 » O » 3 : 2 » = 1/2 » CO_2
consequently products 273° N abs. & 1 atm. = 1 cbm.

§ 139. **Combustion of liquid Hydrocarbons.** Similar as the experiments on combustion of *solid carbon* lead to the conclusion, that in the process of gasifying solid carbon, 2/7 of the entire theoretical heating value of carbon become latent, so that in the combustion of solid carbon, only 5/7 of the heating value make their appearance as *sensible heat* (§ 117), so does author find by investigating the experiments on combustion of *liquid hydrocarbons*, that in the process of gasifying the *liquid carbon* contained in these compositions before combustion takes place, 1/7 th of the entire theoretic heating value of carbon becomes latent, while 6/7 th of the heating value are coming forth os sensiale heat.

In § 115 is shown, that 1 kg. *aeriform carbon* in burning to CO_2 produces 11560 calors of sensible heat; consequently will 1 kg. of *liquid carbon* produce

$11560 \times 6/7 = 9908^{4}/_{7}$ calors.

As demonstrated in § 120, does the *separating* of 1 kg. hydrogen from its combination with carbon, absorb (make latent) 17340 calors, while for each 1 kg. hydrogen 17340 calors appear as sensible heat. — A few examples will explain the combustion of liquid hydrocarbons:

§ 140. **Dyallyl.** C_6H_{10} liquid. *By experiment: 11319·2 cal.*
6 cbm. C à 60/56 kg. = 360/56 kg., in 1 kg. = 36/41 kg. C
10 » H à 5/56 » = 50/56 5/41 » H
36/41 kg. C à $9908^{4}/_{7}$ cal. = $8700^{60}/_{287}$ cal.
5/41 » H à 17340 » = $2114^{182}/_{287}$ » = $10814^{242}/_{287}$ cal.

§ 141. **Hexane** C_6H_{14} liquid. *By experiment*: 11501·2 cal.
6 cbm. C à 60/56 kg. = 360/56 kg., in 1 kg. = 36/43 kg. C
14 cbm. H. à 5/56 » = 70/56 » 7/43 » H
36/43 kg. C à $9908^{4}/_{7}$ cal. = $8295^{165}/_{301}$ cal.
7/43 » H à 17340 » = $2822^{238}/_{301}$ » = $11118^{102}/_{301}$ cal.

§ 142. **Styrol** C_8H_8 liquid. *By experiment*: 10047·7 cal.
8 cbm. C à 60/56 kg. = 480/56 kg., in 1 kg. = 12/13 kg C
8 cbm. H à 5/56 » = 40/56 » 1/13 » H
12/13 kg. C à $9908^{4}/_{7}$ cal. = $9146^{34}/_{91}$ cal.
1/13 » H à 17340 » = $1333^{77}/_{91}$ » = $10480^{20}/_{91}$ cal.

§ 143. **Petroleum** C_6H_{14} spec. grav. 0·800 *By experiment*: 11045·7 cal.
6 cbm. C. à 60/56 kg. = 360/56 kg., in 1 kg. = 36/43 kg. C
14 » H à 2/66 » = 70/56 7/43 » H
36/43 kg. C × $9908^{4}/_{7}$ cal. = $8295^{165}/_{301}$ cal.
7/43 » H × 17340 » = $2822^{238}/_{301}$ » = $11118^{102}/_{301}$ cal.

Combustion of liquid C. H. O. compounds.

§ 144. The compounds consisting of carbon, hydrogen and oxygen devellop in combustion much less sensible heat than hydrocarbons not containing oxygen, because every 8 parts (by weight) of O in the compound already are combined with 3 parts, by weight, of C, or every 2 parts by volume of O with 1 part C (gas), which consequently neutralizes its power to produce heat.

§ 145. **Acetylenclicarbondioxide.** $C_4H_2O_4$. *By experiment*: 2693·9 cal.
4 cbm. C à 60/56 kg. = 240/56 kg. C; in 1 kg. = 24/57 kg. C
2 » H à 5/56 » = 10/56 » H = 1/57 » H
4 » O à 80/56 » = 320/56 » O = 32/57 » O
Of the 24/57 kg. C are 12/57 kg. neutralized by 32/57 kg. O; and combustible:
12/57 kg. C × $9908\,{}^{4}/_{7}$ cal. = $2086\,{}^{2}/_{133}$ cal.
1/57 » H × 17340 » = $304\,{}^{28}/_{133}$ » = $2390\,{}^{30}/_{133}$ cal.

§ 146. **Fumardioxide** $C_4H_4O_4$. *By experiment*: 2752 cal.
4 cbm. C à 60/56 kg. = 240/56 kg. C; in 1 kg. = 12/29 kg. C
4 » H à 5/56 » = 20/56 » H = 1/29 » H
4 » O à 80/56 » = 320/56 » O = 16/29 » O.
Of the 12/29 kg. are 6/29 kg. neutralized by 16/29 kg. O; and combustible:
6/29 kg. C × $9908\,{}^{4}/_{7}$ cal. = $2050\,{}^{10}/_{203}$ cal.
1/29 » H × 17340 » = $597\,{}^{189}/_{203}$ » = $2647\,{}^{199}/_{203}$ cal.

§ 147. **Safrol.** $C_{10}H_{10}O_2$ *By experiment*: 7677·6 cal.
10 cbm. C à 60/56 kg. = 600/56 kg. C; in 1 kg. = 60/81 kg. C
10 » H à 5/56 » = 50/56 » H = 5/81 » H
2 » O à 80/56 » = 160/56 » O = 16/81 » O.
Of the 60/81 kg. C are 6/81 kg. C neutralized by 16/81 kg. O; and combustible:
54/81 kg. C × $9908\,{}^{4}/_{7}$ cal. = $6605\,{}^{5}/_{7}$ cal.
5/81 » H × 17340 » = $1070\,{}^{10}/_{27}$ » = $7676\,{}^{16}/_{189}$ cal.

§ 148. **Hexahydromallitdioxide** $C_{12}H_{12}O_{12}$. *By experiment*: 2659·8 cal.
12 cbm. C à 60/56 kg. = 720/56 kg. C.; in 1 kg. = 12/29 kg. C
12 » H à 5/56 » = 60/56 » H = 1/29 » H
12 » O à 80/56 » = 960/56 » O = 16/29 » O
Of the 12/29 kg. C are 6/29 kg. neutralized 16/29 kg. O; and combustible:
6/29 kg. C × $9908\,{}^{4}/_{7}$ cal. = $2050\,{}^{10}/_{203}$ cal.
1/29 » H × 17340 » = $597\,{}^{189}/_{203}$ » = $2647\,{}^{199}/_{203}$ cal.

Combustion with atmospheric air (with 0·0003 CO_2).

§ 149. If gases or other substances are burnt with *atmospheric air* instead of with *oxygen*, then for *every 1 cbm. of oxygen* 4·7888 cbm. of air, and for *every kg. of 1 oxygen* 4·3337 kg. of air, are required for the combustion. To the products of the combustion consequently must be added:

pr. 1 cbm. oxygen, = 3·7888 cbm. nitrogen, carbon dioxide and argon,
and pr. 1 kg. oxygen, = 3·3337 kg. nitrogen, carbon dioxide and argon.

Laboratory and working temperature.

§ 150. In order to reduce experimental results and observations with ease, correctly to normal temperature (273^0 N abs.) all such experiments, where exact weighing and measuring is nessecary, should be performed in a temperature of 18^0 N (291^0 N abs.), which in temperate climates always can be obtined, in winter by heating and in summer by ventilating, and which besides is a pleasant and wholsome temperature to live and work in. In tropical climates 27^0 N (300^0 N abs.) will be convenient, and for experiments where a lower temperature is required, 9^0 N (282^0 N abs.).

The temperatures 273^0 — 282^0 — 291^0 and 300^0 N abs. are in proportion as 91 : 94 : 97 : 100, and the reduction, for instance, of a measured volume of gas to 0^0 N (273^0 N abs.) is a very simple calculation.

Meteorology.

§ 151. The atmospheric pressure varies in direct ratio to the force of gravity, and consequently the column of mercury in the barometer will, under otherwise equal circumstances, rise higher near the poles than at the equator. According to the mean barometrical readings for various latitudes, published in the »International meteorological tables. Paris 1890,« author has calculated and constructed Diagram I for 0^0 to 70^0 latitude and sea level. The mean barometrical height of mercury at the latitude of international gravity, 41^0 10′ north. lat. = 759·72353 mm of mercury (§§ 2, 3, 4, 5) is in the diagram I and throughout in this volume, adopted as the international atmospheric pressure, and this pressure can be read off with accuracy on column P.·Atm. for any latitude between 0^0 and 70^0, while column V shows the volume which 1 cbm. of air of normal atmospheric pressure would occupy under any other latitude.

Normal Atmospheric Pressure

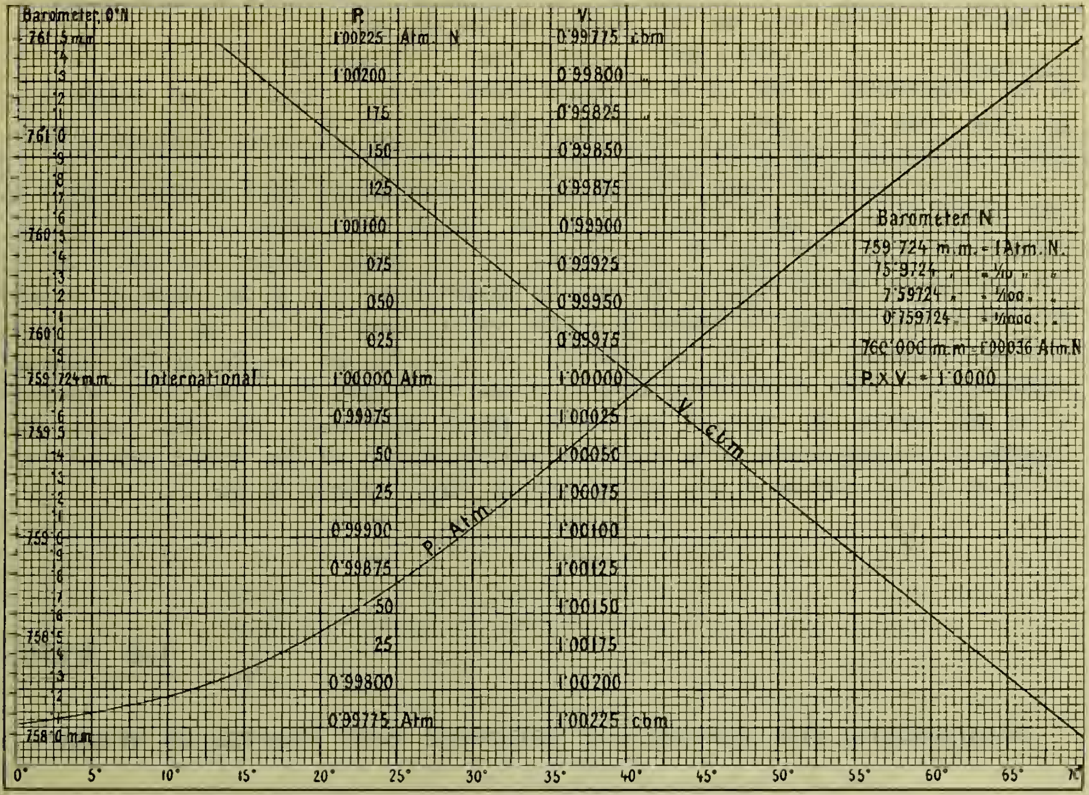
at 41^0 10′ geographic latitude and sea level, and reduction of Barometer readings of 0^0 to 70^0 lat. to normal pressure. (Diagram I.)

Example. Required: the mean normal atmospheric pressure at 31^0 30′ lat. Where abscissa from 31^0 30′ intersects curve P. Atm., does ordinate from point of intersection, show on vertical column P. the required pressure = 0·99920 atmosphere (759·67 mm of mercury) and on column V. the volume due to that pressure = 1·00080 cbm.

Example. Required latitude, where the mean atmospheric pressure is = 1·00145 atmosphere.

Where the ordinate from vertical column P 1·00145 atm. intersects curve P Atm., does abscissa from the point of intersection show on scale of latitudes the required 59^0 lat. One cbm. air of 1·00000 atm. normal pressure is at this latitude = 0·99855 cbm.

Diagram I.



Geographic Latitude.

The Diagonale V. cbm. please consider annulled.

Vapour of water contained in the atmosphere.

§ 152. As shown in § 67 and 68 does water evaporate at all temperatures above $219^3/_8{}^0$ N abs. (— $53^5/_8{}^0$ N). The vapour which constantly (at temperatures below + 100⁰ N rises, from the surface of water, and mixes with the air, takes the temperature of the surrounding air, and has then the pressure due to that temperature (Tab. XIX a and diagram F & G). One cbm. dry air can absorb 1 cbm. of such vapour, and is then *saturated with vapour.* The pressure of such saturated air, is = the pressure of the dry air + the pressure of vapour due to the temperature of the air.

If for instance the Barometer stands at 1·000 atm. N and the air at 0⁰ N (273⁰ N abs.) is saturated with vapour of water, then this vapour will have a pressure = 0·0042 atm., and the *dry air* in the mixture of air and vapour will have a pressure = 1·0000 atm. — 0·0042 atm. = 0·9958 atm. At 10⁰ N (283⁰ N abs.) and 1·0000 atm. barometer, the pressure of the *dry air*

= 1·0000 atm. — 0·0100 atm. = 0·9900 atm.

At 10^0 N temperature and 1·0253 atm. barometer, the pressure of the vapour will be as before = 0·0100 atm. and the pressure of the dry air

= 1·0253 atm. — 0·010 atm. = 1·0153 atm.

If the temperature of the air is increased above 0^0 N it expands, and weighs less pr. cbm. than at 0^0, and if the air is cooled below 0^0 N it contracts and weighs more pr. cbm. than at 0^0 N.

The subjoined Table XXIV shows, for temperatures 243^0 N abs. to 373^0 N abs. (— 30 N to + 100^0 N Col. 1 & 2) the volume and weight of 1 cbm. dry air (with 0·0003 CO_2) of 1 atm. N and of 273^0 N abs. initial temperature (col. 3 & 4); the pressure of vapour, due to the various temperatures (col. 5) the pressure of dry air, due to the pressure of vapour at 1 atm. of barometer (col. 6); the weight of the dry air, contained in 1 cbm. of *saturated air* (col. 7); the weight of the vapour, contained in 1 cbm. of saturated air (col. 8) and the weight of 1 cbm. of the mixture of air and vapour at 1 atm. of barometer. Based upon these calculated values the diagram K is constructed, from which without calculation all the values can be read off every 1^0 N between — 30^0 till + 100^0 N (243^0 till 373^0 N abs.

Tab. XXIV.

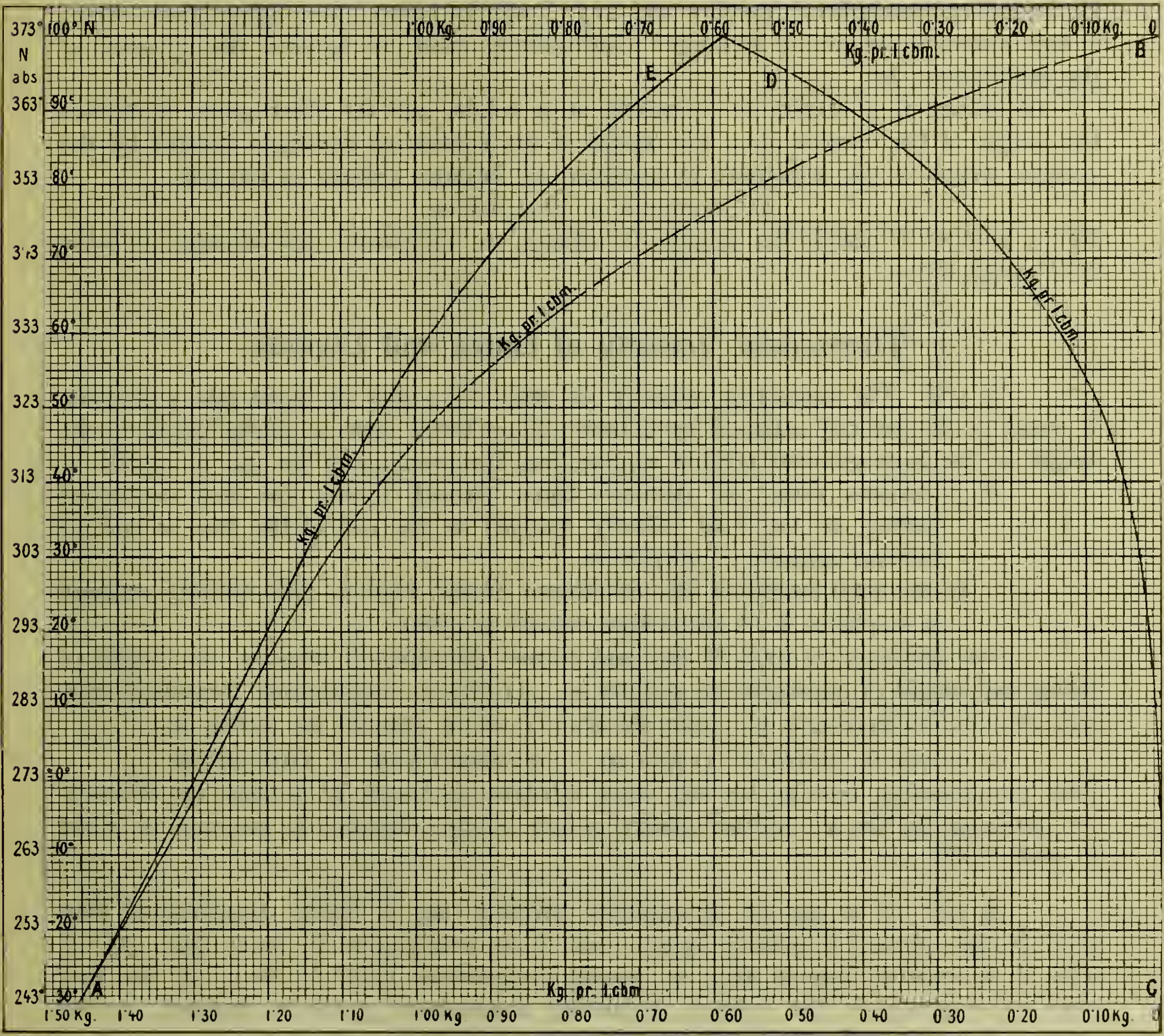
Atmospheric Air (with 0·0003 CO_2) saturated with Vapour of Water

1 cbm. of normal atmospheric pressure, and 243^0 N abs. till 373^0 N abs.

Temperature. abs. ^{0}N. ± ^{0}N		Volume of Air. cbm.	Weight of 1 cbm. Air. 1 Atm. Pressure.	Vapour and Air mixed 1 Atm. Pressure.		Vapour and Air mixed = 1 cbm. of 1 Atm. Pressure.		
				Pressure of Vapour.	Pressure of Air.	Weight of Air pr. 1 cbm.	Weight of Vapour pr. 1 cbm.	Weight of Mixture pr. 1 cbm.
243	— 30	0·89011	1·4524	0·0001 Atm.	0·9999 Atm.	1·4523 kg.	0·00009 kg.	1·45239 kg.
253	— 20	0·9231	1·3950	0·0005 »	0·9995 »	1·3943 »	0·00043 »	1·39473 »
263	— 10	0·9634	1·3420	0·0016 »	0·9984 »	1·3400 »	0·00133 »	1·34133 »
273	± 0	1·0000	1·2928	0·0042 »	0·9958 »	1·2866 »	0·00337 »	1·28997 »
283	+ 10	1·0366	1·2471	0·0100 »	0·9900 »	1·2346 »	0·00775 »	1·24235 »
293	» 20	1·0733	1·2046	0·0210 »	0·9790 »	1·1793 »	0·0157 »	1·1950 »
303	» 30	1·1099	1·1648	0·0390 »	0·9610 »	1·1194 »	0·0282 »	1·1476 »
313	» 40	1·1465	1·1276	0·0710 »	0·9290 »	1·0475 »	0·0498 »	1·0973 »
323	» 50	1·1832	1·0927	0·1220 »	0·8780 »	0·9594 »	0·0829 »	1·0423 »
333	» 60	1·2198	1·0599	0·2000 »	0·8000 »	0·8479 »	0·1318 »	0·9797 »
343	» 70	1·2564	1·0290	0·3180 »	0·6820 »	0·7018 »	0·2034 »	0·9052 »
353	» 80	1·2931	0·9998	0·4630 »	0·5370 »	0·5369 »	0·2877 »	0·8246 »
363	» 90	1·3297	1·9723	0·6840 »	0·3160 »	0·3072 »	0·4133 »	0·7205 »
373	» 100	1·3663	0·9492	1·0000 »	0·0000 »	0·0000 »	0·5881 »	0·5881 »
1	2	3	4	5	6	7	8	9

Diagram K.

§ 141



In Diagram K indicates:

Curve A-B the weight of 1 cbm. dry air of normal atmospheric pressure from 243^0 N abs. till 373^0 N abs.
Curve C-D the weight of 1 cbm. vapour of water of temperatures 243^0 N till 373^0 N abs.
Curve A-E the weight of 1 cbm. of air saturated with vapour of 1 atm. and temperatures from 273^0 N till 373^0 N abs.

Homogeneous Columns of Liquids and Gases 1 Atm. N.

§ 153. The normal atmospheric pressure is according to § 5, at temperature 273^0 N abs. $= 0·75972353$ m of mercury and
$= 10·330442$ m of water.
Hydrogen of atmospheric pressure and 273^0 N abs. is 11200 times lighter than water; a homogeneous column of hydrogen consequently must, to balance the pressure of the atmosphere, be

$10·330442$ m $\times$ $11200 = 115700·95$ m in height, and for other gases or liquids the height of the column is = the height of the column of hydrogen *divided* by the *relative weight* of the substance in question, for instance column of oxygen

$$115700·95/16 = 7231·304 \text{ m}.$$

For a number of gases the heights of column are calculated, and arranged in table XXV page 68.

Theoretical Velocity of Gases and Liquids.

§ 154. The theoretical velocity of efflux of a gas or liquid into a vacuum, is equal to the velocity attained by a body falling freely from a height, equal to the height of the homogeneous column representing the pressure of the gas or liquid.

If g denotes *twice* the distance fallen through during the first second of falling, or the final velocity attained at the end of the first second, *at normal latitude* $= 9·8123$ m.

h the total height of fall, or column of gas, then is, final velocity attained $v = \sqrt{2g \times h}$ = *theoretical velocity of efflux.*

For *hydrogen* of 273^0 N abs. and normal atmospheric pressure the height of falling and height of homogeneous column is $= 115701$ m, consequently theoretical velocity of efflux of hydrogen of 1 atm. & 273^0 N into a vacuum pr. *second*, is

$$v = \sqrt{2 \times 9·8023 \times 115701} \text{ m} = \sqrt{2268271·8246} = 1506\,0783 \text{ m}.$$

The corresponding velocity for any other substance is found by dividing the velocity for hydrogen by the $\sqrt{\ }$ of the relative weight of the substance in question, as given in table XXV.

§ 155. If a gas of atmospheric pressure has a higher temperature than 273^0 N abs., then it is relative lighter, and if the temperature is lower than 273^0 N abs. it is relative heavier than at normal temperature (273^0 N abs.). In the first case consequently is the column, balancing atmospheric pressure, heigher, in the second case lower, than shown in tab. XXV col. 3 in proportion as

T (273^0 N abs.) : t (the abs. temperature of the gas in question)

and in proportion as $\sqrt{T} : \sqrt{t}$ is the velocity of efflux of the heated gas quicker, and of the cooler gas slower than given in the table.

§ 156. *Compressed gases* would in consequence of their heigher pressure have an increased velocity of efflux, if not their relative weight increased in equal ratio as their pressure. This being the case, it follows, that the velocity of efflux into the vacuum is equal for all pressures, but of the compressed and heavier gas more mass (weight) will flow out than of the uncompressed gas.

Tab. XXV.

Homogeneous Columns of Gases and Liquids

which balance the normal atmospheric pressure.

Theoretical Velocity of Efflux

into a Vacuum, m. pr. Second.

Substance. of atm. pressure & 273^0 N abs.	Relative weight.	Height of Column m.	$\sqrt{}$ of relative weight.		
Hydrogen	1	115701	1	The velocity of efflux for hydrogen 1506·078 m. pr. sec. divided by $\sqrt{}$ of the relative weight of other gases (Col. 4) gives the efflux for these (Col. 6).	1506·078 m.
Helium	4	28925	2		753·039
Methane	8	14463	2·8284		532·560
H_2O	9	12856	3·0000		502·026
Carbon	12	9642	3·4641		402·380
Acetylene	13	8900	3·6055		417·659
Nitrogen Carbon monoxide Ethylene	14	8264	3·74165		402·480
Ethane	15	7713	3·8730		388·866
Oxygen	16	7231	4·0000		376·520
Argon Allylene	20	5785	4·4721		336·780
Propylene	21	5510	4·5826		328·623
Carbon dioxide Propane	22	5259	4·6904		320·700
Butylene	28	4132	5·2915		284·600
Butane	29	3990	5·3852		279·280
Pentane	36	3214	6·0000		251·010
Benzene	39	2967	6·2450		185·270
Dypropyl	43	2691	6·5574		176·480
Coal Gas (17 candles)	5·853	19768	2·4180		622·860
Steam of Water (1 atm., 373^0 N abs)	6·587	17565	2·5670		586·710
Water Gas	7·922	14605	2·8142		535·210
Dowson Gas	11·100	10424	3·3167		454·050
Generator Gas	12·763	9065	3·5721		421·634
Atm. Air (with CO_2)	14 47935	7990·7	3·8062		395·712
Water (liquid)	11200·000	10·330442	105·8300		14·231
Mercury (liquid)	152270·000	0·759723	390·2100		3·859
1	2	3	4	5	6

§ 157. If gas does not flow out into a vacuum, but into the atmosphere or against any other counter pressure, then only the *difference* between the moving pressure and the counter pressure is to be taken as the driving homogeneous column, and the velocity due to that height will be the velocity of efflux.

§ 158. **The relative weight of saturated steam** (H_2O). The relative weight of steam (the weight of *hydrogen* of atmospheric pressure and 273^0 N abs. being = 1) is found, if the *weight of 1 cbm.* of steam of the temperature and pressure in question is *multiplied* by 11·2, or if the coefficient 11·2 is *divided* by the number of cbm. in 1 kg. of such steam.

Tab. XX col. 4 and diagrams F & G give the weights pr. 1 cbm. and tab. XIX col. 12 and diagrams F & G the volumes pr. 1 kg. of steam.

Example: 1 cbm. of steam of 1 atm. and 373° N abs. weighs 0·588137 kg.; relative weight = 0·588137 kg. × 11·2 = 6·58713.

1 kg. of steam of 1 atm. and 373° N abs. = 1·7002849 cbm.
relative weight = 11·2/1·7002849 cbm. = 6·58713.

§ 159. **The relative weight of gases of any pressure and temperature** is found by formula:

$$r = \frac{P \times R \times 273^0 \text{ N abs.}}{t}$$

where R indicates the relative weight of the gas in question at atm. pressure and 273° N abs. (page 11 tab. I col. 5),
P the pressure (in atmospheres) of the gas in question,
t the absolute temperature » » » »

Example: required, *relative weight* of *oxygen* of 4 atm. and 490° N abs.

$$\text{relative weight } r = \frac{4 \text{ atm.} \times 16 \times 273^0 \text{ N abs.}}{490^0 \text{ N abs.}} = 35·453.$$

Required, relative weight of nitrogen of $^1/_2$ atm. and 224° N abs.

$$\text{relative weight } r = \frac{^1/_2 \text{ atm.} \times 14 \times 273^0 \text{ N abs.}}{224^0 \text{ N abs.}} = 8·531.$$

WELLCOME LIBRARY INSTITUTE